In this Issue: Steam Superheaters for Locomotives; A., T. & S. F. Ry.—Building the Lighthouse on Miah Maul Shoal, Delaware Bay.—Sewage Experiment Station, Mass. Institute of Technology.—Market Prices of Engineering Materials.

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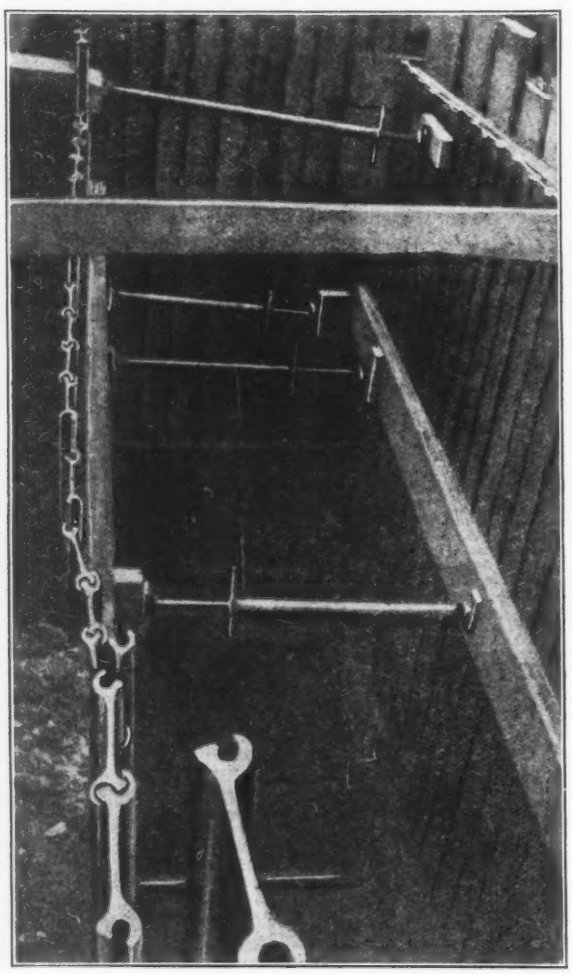

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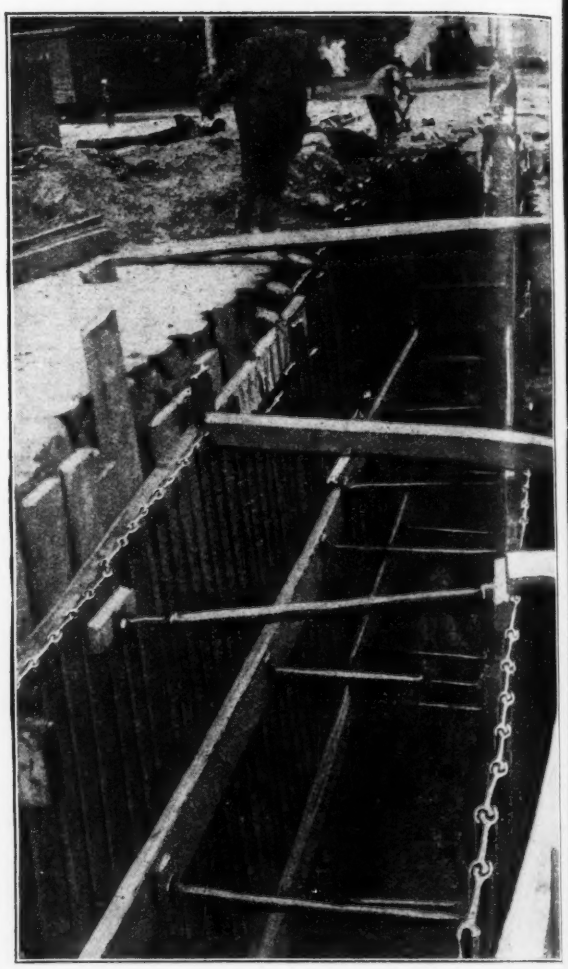

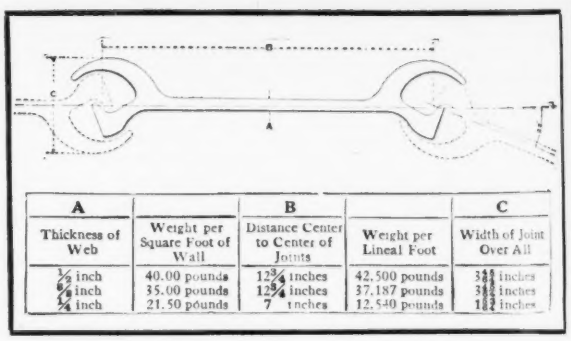

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A Reinforced-Concrete Girder Bridge in an Earthquake Region.

At Messina, Sicily, where such havoc was wrought by an earthquake a year and a half ago, there has been erected recently a rather attractive bridge of reinforced concrete, shown by the photographic view herewith. This bridge, incidentally, is one of the first permanent structures to be completed in the rebuilding of the city. It is known as the Ponte Regina Elena. Special effort was made to give it an attractive finish by ornamentation of the girder faces as well as in the disposition of the general outline of the structure. The simple gas-pipe railing is not out of harmony with the heavier appearance of the body of the bridge.

While the bridge was constructed by an Italian contractor, M. G. Cervello & Co. of Palermo and Messina, an American type of reinforcement, that of the Trussed Concrete Steel Co., of Detroit, Mich., was employed. The central span of the bridge is 39.4 ft. (12 m.) in the clear, and each of the two side spans is 12.6 ft. (3.85 m.) in the clear. The deck of the bridge is 24.6 ft. (7.5 m.) wide, of which 30 ins. on either side is represented by the overhang of the sidewalk, the outside main girders being 19.7 ft. (6.0 m.) 0 to 0. There are five longitudinal girders, spaced 3.77 ft. (1.15 m.) apart in the clear. Each girder is 32 ins. deep (including the 5-in. floor slab); the outside girders are 10 ins. thick, the others 12 ins. The end filleting of the girders contains diagonal reinforcing bars arranged like brackets, and these are tied to the up-and-down reinforcement of the piers.

We are indebted for the photograph and most of the above data to Mr. S. M. Fechheimer of the Trussed Concrete Steel Co., who however was unable to give information as to the means used for producing the face ornamentation or the very uniform face finish.

A REINFORCED-CONCRETE GIRDER BRIDGE JUST BUILT IN MESSINA, SICILY.
(Central span, 39.4 ft. clear. Depth of girders, 32 ins.)

Dustless Roads.*

The short word "tarring" can be usefully employed to cover the general subject of waterproofing our road surfaces so as to render the road impervious. The evolution in road engineering and maintenance therefore consists in waterproofing our roads by one or other of the bitumens, tars, pitches, whether natural or artificial, which offer themselves in ample quantity and at reasonable prices for waterproofing purposes.

Setting aside the temporary palliatives of watering our roads with chemical preparations which keep the road damp by the absorption of moisture from the air, the treatment which has been most successful in rendering our roads dustless has been by the surface application of tar applied either by hand or by machine. By this method great lengths of road have been rendered dustless for a whole summer season, the mud in the winter following has been reduced in quantity, and in some cases the application has lasted for more than one season. Moreover, there is almost unanimous testimony that the whole cost of the treatment is more than saved by the increased durability of the road, and already many surveyors are able to make a strong case for the extension of the treatment solely on the ground of economy alone.

In Fulham, where only a very light waterproofing dressing was given, Mr. Wood, the surveyor, stated that he had removed in 1908-9 only 190 [long] tons of sweepings and mud per mile instead of 390 tons, as formerly, and this of itself shows that not only was the amount of material worn by the traffic from the surface greatly reduced, but that the working up of the subsoil to the surface was also prevented by the application of tar.

These satisfactory financial results, which were known to a certain extent in 1908, would have caused a very great increase in surface treatment during 1909 if it had not been for the exceptional nature of the season, as there were very few days during the spring and summer of 1909 which were suitable for satisfactory tarring.

The committee has already obtained a considerable number of replies to a circular letter sent out to surveyors of the South of England, and from those received up to date, and which relate to 4,513 miles of main roads in the home and southern counties, it is shown that the length of roads tarred and rendered dustless has increased from 393 miles, or 9½%, in 1908, to 657 miles, or about 16%, in the year under review, so that if the same proportion has been observed throughout the kingdom we should expect to find that nearly 4,000 miles have been dealt with, although, probably, as the rainy weather was more prevalent in the north than in the southern counties, the proportion of roads intended to be treated, but which were not treated, is probably larger in the north than in the south.

As regards the second and more permanent mode of treatment, which is that of remaking the whole of the surface of the road with tar-macadam, this is undoubtedly the most permanent and satisfactory method, and when a road has to be resurfaced it is also the most economical in the end. A good deal of progress has been made in this direction; all over the country short lengths have been experimentally laid, and the results have been so satisfactory that the surveyors have signified their intention to increase this method of repairing at a rapid rate. Several surveyors, notably those in West Sussex and in the Staines district, have introduced an intermediate method, which is likely to be of great importance in improving our narrower second-class roads. In place of relaying the whole width of the road with macadam, the worn portions or tracks which have been made by the traffic have been cut out and filled in squarely and smoothly with the best class of tar-macadam, well beaten in and afterwards rolled, and the whole surface of the road afterwards tarred superficially. This gives two broad, smooth tracks, which offer the least resistance to the vehicles, so that automobilists, in common with the other traffic, prefer to use these tracks, and the wear and tear of the rest of the road are thereby saved. It is probable that we shall see a considerable extension of this system for the remaking of the narrower and secondary roads of the kingdom.

During the year 1909 the club has been requested by many of its members and associates to use its best efforts to secure dustless roads throughout the country, and this desirable object has been furthered by meetings with those responsible for the construction and maintenance of the roads, and in many cases with conspicuous success. Road surveyors and others have shown themselves to be well aware of the national importance of the question, and some of them have already stated that it must now be taken as an accepted fact that automobile traffic is the traffic of the time and of the future, and that therefore no time must be lost in resurfacing the roads of the country to suit this form of traffic. It is satisfactory to be able to record that this resurfacing of the roads on a more scientific basis, instead of being a costly undertaking, as was thought at one time, will, if carried out in the manner that past experience dictates, prove a real benefit to the ratepayers.

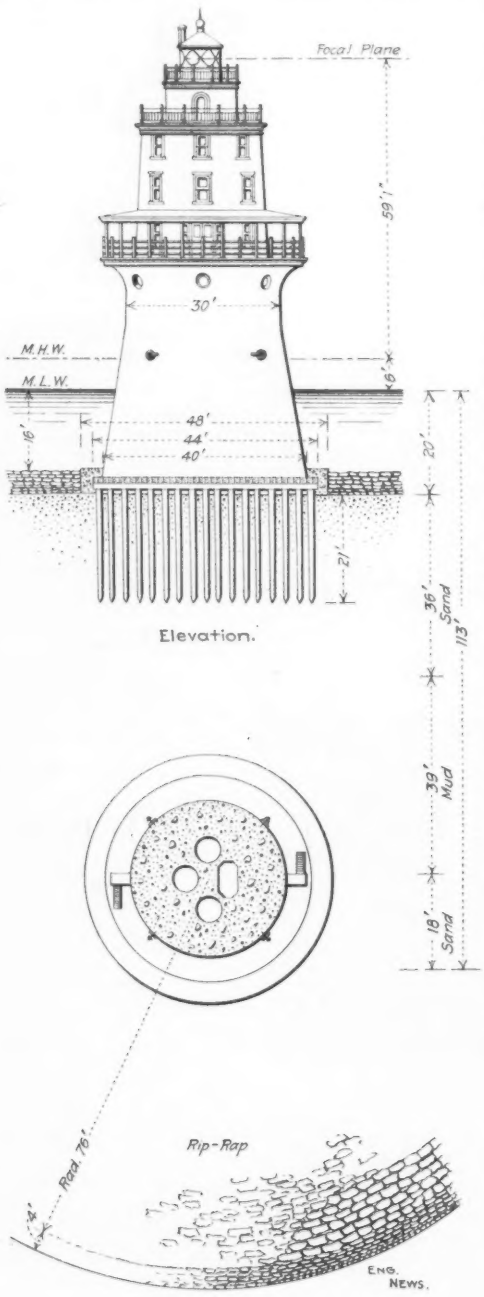
Finally, it must not be overlooked that the application of tar to the surface of the roads is extremely valuable from the sanitary point of view. It is undoubtedly a fact that the very small quantity of dust arising from a tar-treated road is far less liable to carry disease germs than the ordinary dust from untreated roads.

*From 1909 report of Dust and Dustless Roads Committee of the Royal Automobile Club of England. The full report appeared in the London "Surveyor" for March 18, 1910.

Building the Miah Maul Shoal Lighthouse.

By THOS. J. ROUT, JR., and A. E. ARLEDGE.*

In 1906 Congress appropriated $75,000, for the construction of a lighthouse on Miah Maul Shoal, Delaware Bay. This shoal is 1¾ miles long and extends parallel with the main ship channel. It is 15 miles northwest of Cape May and 4 miles south of the Elbow of Cross Ledge lighthouse erected in 1907. Although the shoal is only four miles south of the Elbow of Cross Ledge light and 4½ miles north of Fourteen-Foot Bank Light, it was deemed advisable in the interest of navigation to mark the northerly end of it.



Elevation. Plan.

Fig. 1. The Miah Maul Shoal Lighthouse, Delaware Bay.

At this point the bay is 13 miles wide and the site has little protection against storms. The nearest harbor is Maurice River, 12 miles away, and the nearest land is Egg Island Point, N. J., five miles, the Delaware shore being eight miles away.

The site decided upon for the lighthouse has a submerged depth of 20 ft. at mean low water and the tides have a mean rise and fall of 6 ft. The tides flow with a velocity of 3½ mi. per hr. In June, 1907, the Government made a test boring on the site to a depth of 100 ft. The material penetrated was 36 ft. of sand, 40 ft. of mud, and 24 ft. of sand.

Two classes of foundations were considered for the structure; the pneumatic caisson foundation or a grillage on piles. The latter method was adopted as it was thought to be much less expensive. This, however, did not prove to be the case. In 1907 the pneumatic caisson foundation for Elbow of Cross Ledge light station was erected and sunk to a depth of 9 ft. 8 ins. at a cost of $60,000 which included the iron work. The Miah Maul Shoal foundation shell was practically the same size and its cost complete was $59,000, only $1,000 less than the foundation at Elbow of Cross Ledge light station, the high cost being due to the excessive bid for the pile foundation.

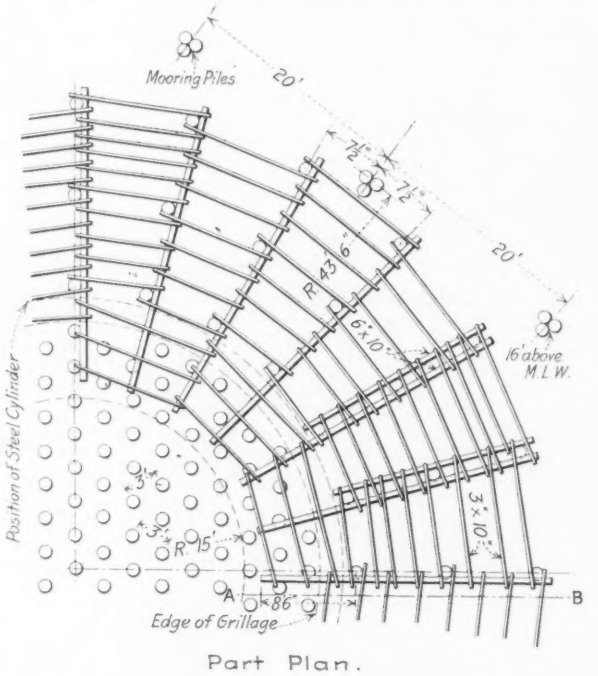
The foundation shell is 40 ft. in diameter at the base and 42 ft. 8 ins. in height. It is composed of 224 1¼-in. cast-iron plates in seven courses, the top course being bell shaped. See Fig. 1.

On January 25, 1908, bids were received for the metal work (approximately 368,000 lbs.) ranging from $8,633 to $27,335, and the work was awarded to the lowest bidder, the Lynchburg Foundry Co., of Lynchburg, Va. On May 12, 1908, bids were received for erecting a working platform, the pile foundation and for depositing 3,000 cu. yds. of riprap. These bids, ranging from $25,166 to $36,750, were high, but the work was awarded to the lowest bidder, The F. K. Wills Co., of Wilmington, Del., as the Government did not care to defer the work till the next summer.

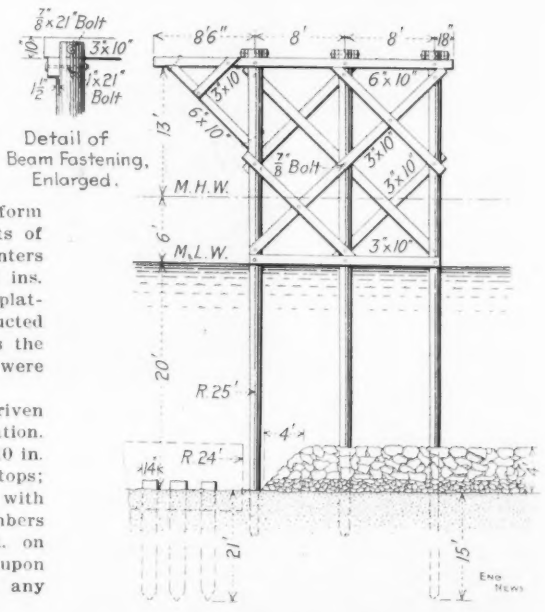
Work on the foundation was commenced at the site July 24, 1908. The platform, to accommodate the storage of materials and to support the quarters for the workmen, contained 14,000 ft. B. M. of lumber, was supported on 39 piles driven 15 ft. into the sand and was securely braced with diagonal 3 × 10-in. timbers. Its deck contained 1,900 sq. ft. and was 13 ft. above mean high water. A quadrant of the circular platform is shown in Fig. 2. The foundation consists of 187, 15-in. white oak piles driven 3 ft. on centers and 18 ft. into the sand, and extending 12 ins. above the bottom of the bay. A temporary platform, 6 ft. above high water, was constructed over the area of the foundation. Upon this the pile driver was erected and all the piles were driven from this structure.

For this platform 18 14-in. piles were driven over the area to be occupied by the foundation. The piles were notched 2 ins. to receive 3 × 10 in. wales, which were bolted to them near their tops; after which all piles were sawed off flush with the wales and in a horizontal plane. Timbers (3 × 10-in.) laid flatwise and about 3 ft. on centers were placed upon these wales and upon these the pile driver could be shifted to any position, on its rollers.

The specifications provided that the piles for the lighthouse foundation should be sawed off in any approved manner, within ½-in. of an established elevation, but the contractor devised a scheme to eliminate the services of divers. A structural-iron tube, weighing about 3,000 lbs., 18 × 18 ins., on the inside, and 30 ft. long, was constructed from four 6-in. channels. This, latticed together with ⅜ × 2-in. pieces, was placed on the bottom over the point where the pile was to be driven. All foundation piles were white oak sawed with heads perpendicular to axis and of the proper length. They were carefully trimmed of all knots and pointed so as to give an equal slope to each of the four bevels, and after pointing they had about a 3 × 3-in. flat at their ends. A pile was placed in this tube and a follower was placed on the head so that the pile could be driven to the exact proper level. The follower was a seasoned oak timber, 15 ins. in diameter and 32 ft. long, well banded at each end and provided with two ¾ × 2-in. iron pins in its lower end to hold it in proper position on the pile head. After a pile was dropped into the tube and the follower placed upon its head thrusting it to the bottom, the water jet was started. The water was supplied through a 1¼-in. pipe reduced to a ¾-in. nozzle and was furnished under high pressure by a double acting horizontal force pump provided with its own boiler. By means of a level and a mark on the follower, the elevation of the pile could be exactly determined. The platform for the engineer's level was built upon the semicircular platform, shown in Fig. 2, so that the jars of the hammer would not disturb it. For fear of brooming the piles, only short blows of the hammer were made, 6 to 8 ft. The driving was very hard especially during the last foot. In many cases this last foot required 50 to 100 6 or 8-ft. strokes with a 2,000-lb. hammer and with a strong water jet. Driving without the jet was practically impossible. In driving the 187 piles only two failures were made. Two piles were broomed and were sawed off by a diver. At the completion of the work, Nov. 28, 1908, a



Part Plan.



Vertical Section A-B.

Fig. 2. Part of the Semicircular Construction Platform; Miah Maul Shoal Lighthouse.

*Superintendents, Fourth Lighthouse District, Wilmington, Del.

xamination was made by a diver and he reported hat the tops of piles were approximately in a orizontal plane. The greatest number of piles ut down in one day (of 14 hours) was 16. After pile was driven the tube was raised about a foot f the bottom by a hoisting engine. By means of

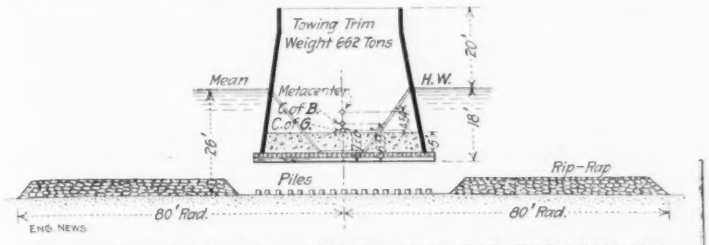


FIG. 3. FLOATED SHELL OF LIGHTHOUSE FOR THE MIAH MAUL SHOAL.

three guys and tackle at the top and bottom of the tube manipulated from the temporary working platform, it could be placed vertically on any desired point.

To prevent the bottom from scouring a 4 ft. layer of riprap containing about 3,000 cu. yds. was deposited around the foundation to a radius of 80 ft.

While work on the piling was in progress, the metal for the foundation shell was delivered at the banks of the Christiana River, about 1½ miles from Wilmington. Bids were invited on Sept. 10, 1908, for erecting the shell and filling it with concrete. These bids ranged from $17,500 to $75,000, and the work was awarded to the lowest bidder, the Sherwood Engineering & Construction Co., of York, Pa. The work was started Oct. 5. A launchway was constructed at the Christiana River and on this a circular grillage, 44 ft. in diameter and consisting of two layers of 156 12 × 12-in. cross timbers, was placed. The grillage had to be water tight. To secure this, a heavy canvas (15-oz.) well saturated with coal tar was spread over the entire area between the two courses of timbers, and all seams between the pieces of the upper course were poured full of coal tar. The lower course of the shell was bolted to this grillage and three courses (18 ft.) of shell plates were erected. All cracks were caulked and a 12-in. layer of concrete was deposited over the grillage. About this time the contractors failed and work was suspended.

On April 7, 1909, bids were again invited to complete the work under the former specifications. These bids ranged from $23,500 to $27,960 and the work was awarded to the Tatnall-Brown Co., of Wilmington, Del. Work was resumed and on July 14 the shell was launched without mishap, in the same manner as a vessel. The structure weighed about 240 tons and had a draft of 5½ ft.

After the structure was launched, three more courses of plates were erected and 4 ft. more of concrete was deposited. It then weighed 662 tons, had a draft of 18 ft., and a freeboard of 20 ft. The center of gravity was 7.22 ft. above the lower face of grillage and the metacenter was 4.54 ft. above the center of gravity. Radial braces 6 × 8-ins., 19-ft. long, 32 in number, had been put in so as to brace the plates above the concrete. The floating shell is shown in Fig. 3, and the details of the metal work, etc., in Fig. 4.

According to the specifications, the United States was to tow the foundation shell to the site and assume all risks until it was sunk on its pile foundation. At 1 p. m., Aug. 17, 1909, the shell left the Christiana River in tow of two lighthouse tenders, which had a combined rating of 1,550 HP. Slow progress was made—about 6 mi. per hr., going with the tide. It was found impossible to make progress against the tide so the vessels anchored during flood. The tide had much influence on the shell and considerable difficulty was experienced in keeping it in the channel. About 4 a. m., and just before reaching the site the hawser (a 13-in. one) parted. The tenders then rounded up on each side of the shell and towed it abreast for the remaining distance, reaching the site at 5.30 a. m., Aug. 18. In order to pass over the 4-ft. course of riprap, deposited around the

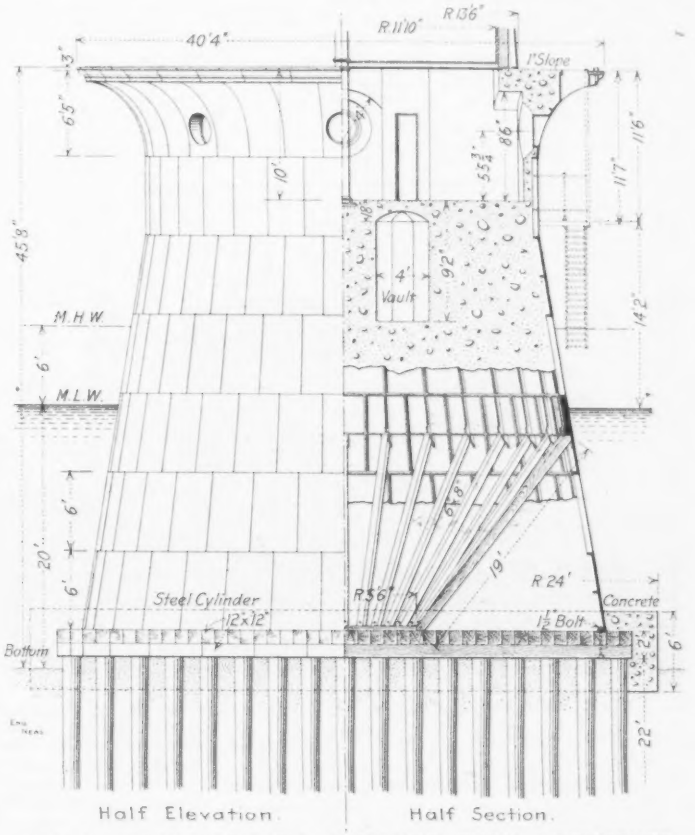


FIG. 4. DETAILS OF SHELL; MIAH MAUL SHOAL LIGHTHOUSE.

site, the shell was placed over the foundation at high tide and secured to the working platform, which was built in a semi-circle, and at low tide water was siphoned into the shell through a 4-in. pipe, sinking it on the pile foundation. When in final position the shell was found to be level within a limit of ¼-in.

When the shell was turned over to the contractor, at the site, it contained about 10 ft. of water. A 4-ft. depth of concrete was deposited under water by means of a tube and with each foot (in depth) of concrete deposited, 3 ft. (in depth) of water was pumped out. When the 4 ft. of concrete was deposited, all the water was pumped out and the remaining concrete was deposited, in air. About 1,250 cu. yds. of concrete was required to fill the shell. It consisted of 112 lbs. of cement to 2 cu. ft. of sand, and 6 cu. ft. of crushed stone (½ to 2-in. sizes). Salt water was used in mixing.

To protect the woodwork against the teredo, a steel cylinder was placed around the grillage. It was 6 ft. in height, 48 ft. in diameter, and consisted of 16 ¼ in. steel plates. The plates were bolted together and the cylinder was lowered by means of blocks and tackle all at one time. It was pumped into the sand 18 ins. and the space between the foundation shell and grillage and the cylinder was completely filled with concrete.

The work was completed in November, 1909, and a temporary gas light has been established on the foundation shell. The superstructure will consist of a three-story iron dwelling, as shown in Fig. 1. When the lighthouse is completed, the weight on the foundation will be as follows:

	Pounds.
Foundation shell	368,200
Grillage and braces in foundation shell	162,000
Concrete in foundation shell	4,537,400
Total	5,067,600
Buoyant effect on the foundation at low water	1,382,400
	3,685,200
Weight of proposed superstructure	317,800
Total weight on foundation	4,003,000

This is approximately 10.7 tons on each pile.

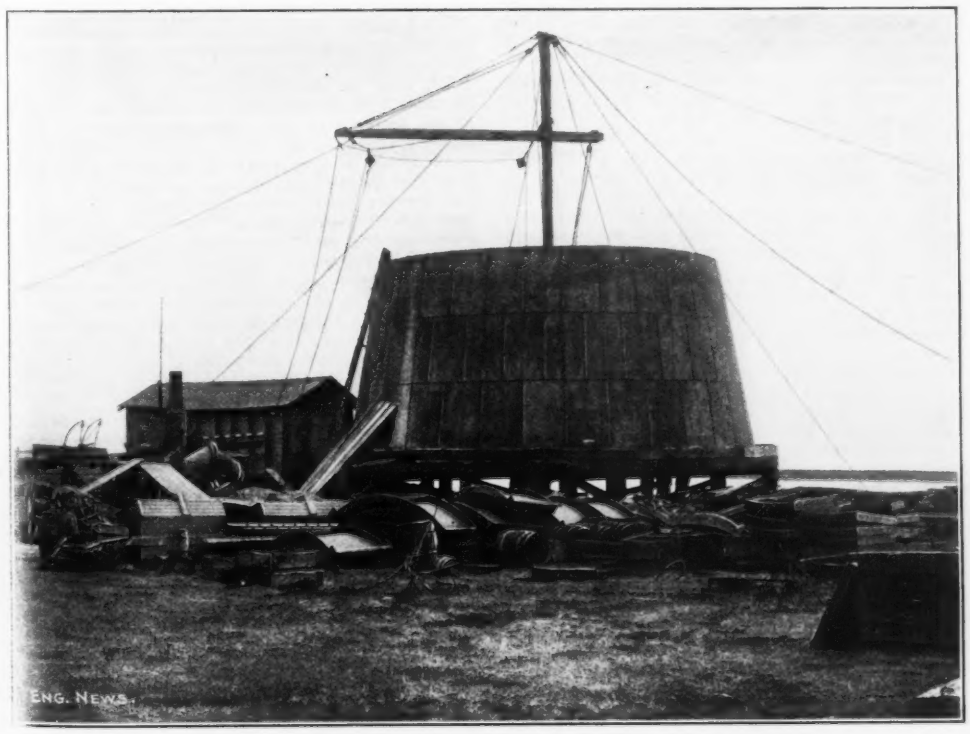


FIG. 5. LIGHTHOUSE SHELL READY FOR LAUNCHING.

An Early Specification for a Steel Bridge; the Glasgow Bridge Over the Missouri River.

The old bridge of the Chicago & Alton Ry. over the Missouri River at Glasgow, Mo., built in 1878-1879 and replaced in 1899 to 1901,* had the distinction of being the first steel truss bridge in America. The tubular arch-ribs of the Eads Bridge over the Mississippi at St. Louis are of steel, and these antedated the Glasgow Bridge by nearly ten years; but they were compression members only, while the three 314-ft. channel spans of the Glasgow Bridge were of steel in all parts, eyebars and rivets as well as compression members.†

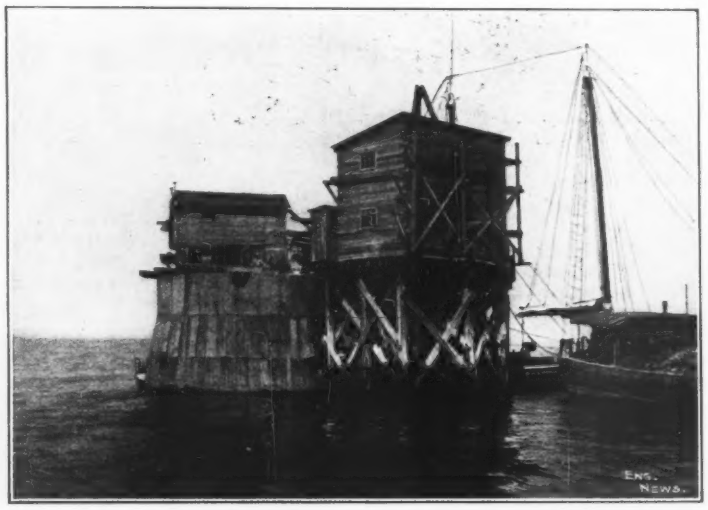


FIG. 6. THE MIAH MAUL SHOAL LIGHTHOUSE DURING CONSTRUCTION.

But a further distinction of the Glasgow Bridge is the fact that its steel was made by the curious "Hay" process, the invention of A. T. Hay, of Burlington, Iowa. The "Hay steel" has been the subject of considerable discussion.‡ It was produced by adding to the metal tapped from either the converter or the open-hearth furnace a compound (the Hay "sponge" or "matte") which Mr. Hay produced in a small furnace by aid (as he asserted) of an electric current. Recarburizer was employed as in ordinary steel production, but in sufficient quantity to give a rather high carbon content, as the chief object of the Hay process was to produce a high-strength steel. The steel used in the Glasgow Bridge contained about 0.40% carbon, and seems to have had a tensile strength of 80,000 to 90,000 lbs. per sq. in. About the same period the Kinzie St. draw-span of the Chicago & Northwestern Ry. over the Chicago River in Chicago was being built, also of Hay steel (this bridge, though begun later, was in fact completed before the Glasgow Bridge), and this metal contained about 0.30% carbon, with correspondingly lower strength. A railway bridge over the Missouri at Plattsmouth, Neb., was also built of Hay steel.

The steel of the Glasgow Bridge gave good account of itself when one span of the structure collapsed during erection, because ice carried out the falsework. The wreckage showed but few breaks, and of the eyebars in particular only four were broken by the fall. Most of the eyebars, though bent and twisted, were reheated and straightened in the shop and were sent back to the bridge to be used. This with 0.40% carbon steel is proof of good quality and careful manufacture.

The process of producing the "Hay matte" was a secret one, carried on by Hay himself at Burlington, and but little is known of its nature or virtues. His descriptions of the theory and working of the process are couched in a language so peculiar as to be unintelligible. In part he claimed that the "matte" had a strong deoxidizing action on the steel, but he also claimed that it added to the steel certain essential metallic elements, which so far as can be judged were meant to include chromium, aluminum and other rare alloy metals. No analyses showing the presence of such elements in metallic form in the "matte" or their presence in any form in the finished product have come to our knowledge.

Whatever the merits of the Hay process may have been, it is certain that Gen. Sooy Smith was strongly impressed by Hay's claims, and became convinced of the great value of the metal. His remarks even so late as 1901 (above referred to) demonstrate this. The conviction led him to draw the specifications for the Glasgow Bridge in such terms as to invite bidders to use Hay steel, and the bridge was actually made of this metal.

Mr. Charles V. Wheeler, of the Firth-Sterling Steel Co., Washington, D. C., has favored us with a copy of these specifications,* and they are reprinted below. Mr. Wheeler's father, C. Y. Wheeler,† was in charge of the manufacture of the steel which it seems was made by the Edgar Thomson Steel Works for Hussey, Howe & Co. of Pittsburg.

*See article by W. D. Taylor on the reconstruction, Eng. News, March 14, 1901, which contains also an outline diagram of the old Whipple truss bridge.

†The two approach spans were made of wrought iron.

‡See Eng. News, April 14, 1877, for a letter from A. T. Hay to U. S. Commission for Testing Iron and Steel; July 25, 1901, for remarks by Gen. Wm. Sooy Smith, W. H. Finley and others, on the Hay steel, and editorial comment thereon; and Aug. 1, 1901, and Aug. 8, 1901, for letters discussing the same subject.

General Specifications for Superstructure of Glasgow Bridge.

[Dated Glasgow, Mo., May 1878.; Accompanied by printed invitation to bid in accordance with the specifications, bids to be submitted to Wm. Sooy Smith, Engineer Glasgow Bridge, at Glasgow, on or before June 15, 1878, 12 noon.—Ed.]

DESCRIPTION OF BRIDGE.

There will be five (5) spans of three hundred and fourteen and two-thirds (314 2-3) feet each, measured from center to center of piers and abutments, and numbered from the East side of the river westward consecutively.

Numbers one, two and three will be above grade or through spans placed at an elevation of fifty (50) feet above high water surface as determined by the surveys of the Engineer of the Bridge, this height being measured from that surface to the lowest point of the Bridge superstructure.

Numbers four and five will be below grade or decked spans placed at the elevation required by the grade of the track which descends from the West end of number three (3) at the rate of forty-five (45) feet per mile.

The clear width shall be sixteen (16) feet between end posts; clear height twenty-one (21) feet above top of rail.

The track stringers, ties and guard rails shall be of wood; all other parts of the bridge superstructure shall be of wrought iron or steel.

If of wrought iron it shall possess the following characteristics: The parts subjected to tensile strain shall be tough, ductile, of uniform quality and capable of sustaining, without fracture, fifty-five thousand (55,000) pounds per square inch of original sectional area in the sizes actually required. It shall also sustain a strain of twenty-five thousand (25,000) pounds per square inch of original sectional area and while so strained endure a sharp blow with a blacksmith's hand hammer without taking a permanent set. A round bar of the same quality and make, one and one-half (1½) inches in diameter, shall be capable of bending through one hundred and eighty (180°) degrees without crack or flaw. Bars of the sizes and shapes actually used shall elongate ten (10) per cent. of their length before breaking and undergo a reduction of sectional area at the point of fractu when broken, of at least twenty-five (25) per cent.

The iron used in parts subjected to compression sh be of uniform quality, tough, fibrous, and capable sustaining a compressive strain of twenty-six thousa (26,000) pounds per square inch of section without ta ing a permanent set.

If the superstructure is built of steel, it shall be uniform composition and quality, as shown by chemic analysis and mechanical tests, tough, and ductile at temperatures from one hundred and twenty (120) degrees above zero to thirty (30) degrees below zero Fahrenheit scale. It shall be capable of sustaining wit out fracture in sizes or shapes actually required a te sile strain of eighty thousand (80,000) pounds per squar inch of original sectional area. It shall elongate least ten (10) per cent. and suffer a diminution of se tional area of at least twenty (20) per cent. in breal ing. It shall sustain a tensile strain of forty-eigh thousand (48,000) pounds per square inch of section an while so strained endure a smart blow with a black smith's hand-hammer without taking a permanent se It shall be capable of being bent cold in a round ba one and one-half (1½) inches in diameter through on hundred and eighty (180°) around a cylinder one (1) inch in diameter without crack or flaw. It shall be a capable of being welded soundly and strongly as good wrought iron without permanent set.

Used in compression it shall resist a compression strain of forty-eight thousand (48,000) pounds to the square inch of sectional area.

In calculating the strain on each part of the bridge superstructure the weight of rails, spikes and joints in the track shall be taken at forty-two (42) lbs. per lineal foot. Timber in track stringers, ties and guard rails shall be estimated at fifty-four (54) pounds per cubic foot, and the weight thus obtained shall be added to that of all the other materials in the superstructure to get its weight or the dead load. The rolling load to be provided for shall consist of two (2) locomotives coupled, moving at a speed of thirty (30) miles per hour, each weighing thirty-six (36) tons on drivers, in a space of twelve (12) feet; total weight of each engine and tender, loaded, sixty-six (66) tons, in a space of fifty (50) feet, and followed by loaded cars weighing twenty (20) tons each, in twenty-two (22) feet.

An addition of ten to thirty per cent. will be made to the strains produced by the rolling loads as above, considered at rest, in those members which are strained directly and suddenly.

Additional strains produced by a pressure of wind of fifty (50) pounds per square foot on the surface exposed must also be provided for, and this is the amount of constant lateral pressure to be resisted by the top and bottom lateral bracings. To the constant pressure upon the surface of the bridge must be added three hundred (300) pounds per lineal foot for that exerted upon passing trains and through them upon the bridge.

If wrought iron is used, the parts subjected to sudden tensile strain shall not be called upon to sustain more than eight thousand (8,000) pounds per square inch of sectional area; those upon which the strain comes progressively may be subjected to a strain not exceeding ten thousand (10,000) pounds per square inch of cross section. If of steel the same factor of safety and the same proportional decrease of strain per square inch will be provided in parts suddenly strained.*

The parts subjected to compression shall be so proportioned as to bear no more than the safe load estimated at one sixth (1-6) their ultimate strength, as determined by Gordon's formula.

Contractors making proposals for the superstructure shall furnish their own designs, accompanied by drawings showing plans, sections and elevation of the structure, and all essential details. They shall furnish strain sheets showing the stress on each member whether in tension or compression both in the vertical trusses and in the top and bottom lateral bracing and drawings (showing forms and dimensions of the parts sustaining these strains), and such forms of cross section shall be employed as will make all the parts of the bridge superstructure most readily accessible for painting. No part less than three-eighths (⅜) of an inch in thickness will be permitted to enter into the construction.

Lock nuts of a pattern to be approved by the engineer of the bridge shall be used on the floor beams, hangers and on other parts of the bridge superstructure, as the engineer of the bridge may direct.

The necessary tests to establish the quality of all the materials to be employed shall be prescribed by the engineer of the bridge and performed by the contractor at his own expense under supervision of the engineer of the bridge or of an expert to be selected by him.

All necessary information as to depth of water, rate of current, variation in water surface, nature and depth of materials of bottom down to bed rock, and all other things affecting the cost of erection of the superstructure will be given by the engineer of the bridge on application to him either in person or by letter.

*A copy is in the library of the American Society of Civil Engineers. The specifications were read to the society at the Cleveland convention of the society June 17, 1879.

†C. Y. Wheeler was a resident of Burlington, Iowa, in the early 70's, being interested in some newspapers there. He became acquainted with Hay, and in 1876 sold out his newspaper interests and rented the plant of the Wyandotte Steel Co. at Wyandotte, Mich., for experimenting with Hay steel, Hay himself having no money for such work. The Hay Steel Co. was subsequently organized, and let licenses for the use of the process. The "matte" was always made by Hay at Burlington.

*A note written in the American Society of Civil Engineers' copy reads, "The factor of safety for later strain may be (3)."

The metal furnished to meet this specification was actually steel, as already noted, except in the case of the approach spans; and this steel was made with the use of "Hay matte."

Some interesting data on the manufacture of the steel for the Glasgow Bridge are contained in an old notebook of C. Y. Wheeler, covering the period June to December, 1878. This book contains records of Bessemer heats most of which seem to have been made for the Glasgow Bridge. During the first month or so, the notes show that the proposition of making a satisfactory product was doubtful. There are records of trial blows, some failures, others successful. There appears also on an early page the following interesting memorandum, undated:

1st. We want tensile members made of iron—or that part of tensile members that require welding.
2d. H. H. & Co. think it better to not hurry too much in regard to giving out the bids until we have time to test [word "eyebars" crossed out], etc. It is probable that the steel would not stand as high as iron and that is bad enough.
3d. We will only furnish metal on tests being accepted from each blow—and then our responsibility must cease, else than that we will guarantee the blow.
4th. We will take all but eyebar and will try to manufacture an eyebar in steel, but if we cannot, want iron accepted in lieu of steel.

The doubt concerning eybars seems to have been settled very soon, in favor of steel (the name Kloman occurring in several notes indicates that the Kloman process of forging eyebar heads was used).*

The memoranda of the individual heats give the carbon percentage and the charge. Most of them have an endorsement such as "Accepted for Compression," bearing on the use made of the steel. It appears that the aim was to get 0.38% carbon in steel for compression members, and 0.42% carbon in tension steel. The actual carbon content was:

	Carbon wanted.	Actual carbon. Range.	Actual carbon. Average.
"Accepted for compression"..	0.38%	0.32—0.40%	0.36%
"Accepted for tension".....	0.42%	0.37—0.50%	0.42%

Some of the heats of eyebar steel are marked "Accepted for pins." A few heats of rivet steel are recorded, these running from .08 to 0.16% carbon, with the note "0.15 carbon wanted." The Hay matte was used in these heats also.

The "Hay steel" heats differed from ordinary Bessemer only by including an addition of the matte amounting to about one-third the spiegel addition. Thus, some typical eyebar heats were

Pig	13,000 lbs.
Spiegel	1,350 lbs.
Mat	400 lbs.

and a rivet-steel heat is recorded as

Pig	16,000 lbs.
Spiegel	150 lbs.
73% Ferromanganese	160 lbs.
Mat	250 lbs.

A few heats of higher-carbon steel are among the lot. These are marked "Steel for H. H. & Co., Frog Steel," and one of them runs:

Pig (incl. 16% steel).....	12,000 lbs.
Spiegel	2,340 lbs.
Mat	400 lbs.
Carbon wanted.....	0.65
Carbon	0.61

The great effect credited to the matte is indicated by the curious memorandum in the record of one of the bridge steel heats:

Heat spoiled by mat lodging and not melting. Heat run into rails.

This was a heat proportioned to give 0.38% carbon, and as the matte apparently could have no recarburizing influence the product doubtless was of a grade in the neighborhood of 0.40% carbon.

As to the nature of the matte, there is only fragmentary information. Mr. William Kent writes, in Engineering News of Aug. 1, 1901, p. 75:

The substance was simply a slag; it was a mixture of silicates of iron, alumina, manganese and some other substances, and may have contained oxides or silicates of chromium, tungsten or nickel. It was black in color, brittle as glass, and non-metallic. No steel chemist believed then, nor will any believe now, that such a substance added to a steel bath in a converter or in a furnace could have any influence whatever on the character of the steel. It would merely melt and pass into the slag, and under the conditions of the steel-melting process no part of it would be reduced to the metallic state or alloy with the steel.

The raw materials for the matte were "ore, chrome and cryolite," the latter doubtless being intended to furnish the aluminum, which Hay made a great point of.

Gen. Wm. Sooy Smith, in speaking of his first acquaintance with Hay (Eng. News July 25, 1901, p. 53), said that the matte was made in an electrical furnace. His description of this furnace represents simply a small cupola, with double wall, having wire windings in the space between the walls. But Hay himself is very definite in calling his apparatus a *magnetic furnace*, and not an electric one. The following amusing letter expresses this clearly:

Office of
HAY STEEL WORKS,
No. 115 Columbia Street,

A. T. HAY.

Burlington, Iowa, March 14, 1879.

C. Y. Wheeler, Esq.,
Pittsburg, Pa.

Dear Sir:—

Your favor of the 11th with Dr. Nes' article and a copy of his Electric Patent recd. I read the article in Manufacturer some days ago and I read the outlines of his patent in 1870. Now the fact is his Electric Patent steel was a failure. This Patent was predicated on the dog Chain Gunbarrel discovery—which was entirely eclipsed by his Pheasant shooting "Codorus Ore" discovery, when he found God Almighty had supplanted his battery and stored up the Crystalized Silicon ore ready to make fine steel direct, and on this he took Patents and issued his silicon Steel circular, and went into business on paper generally and that too like Capt. Bledso's "Steamer Clare Belle" had its day, and like the Keeley Motor and Cressons Ati Incrustator, had many drawbacks. As near as I can find any record of these wonderful discoveries they commence to be heralded in the papers about 1870. While my Caveat was filed relative to minerals in May and July 1866, and in November 15th 1866 filed special paper on my present magnetic coil furnace for "The Reduction of Ores" and "purification of metals" that is my record and the filing of that paper covers the conception of my entire developements. And as far as applying a direct current of Electricity to moulten iron is concerned the Patent Office library showed three several Patents prior to Nov., 1866 (English). Hence Dr. Nes cannot claim that. While I don't apply Electricity, but magnetism and I don't claim to make steel direct either, I first make fine iron and steel is made by ordinary Carbon process. Now Dr. Nes and all other investigators and experimenters will find that fine iron is as essential in fine steel, as "Rabbit meat is in rabbit soup"—and that implies first catch the Rabbit. There is nothing easier than converting iron into steel, but in no instance will your steel grade any higher than the iron it was made from. Dr. Nes from his writings evidently "Knows a great deal more about steel than he will ever be able to find out," in other words, his process if it may be called a process amounts to nothing—and his backers are blackmailers—Don't gratify them to give them dates of my Caveats or any particulars about what the sponge contains. I have up a building out home 26 × 34 ft. with capacity for office store room, Engine Casting floor and 8 furnaces. Will move next week so send along your orders and I will fill 1½ tons per day to start on and if business justifies will put in other furnaces up to 8, and turn out ten barrels per day and more if you want it. Only give me reasonable notice as it will take about 4 days to put in an extra furnace.

Yours truly,

A. T. Hay.

P. S.—Go careful on that old sponge. The new is first class. H.

In a letter (July 25, 1881) from Hay to Wheeler, occurs the suggestion of using tungsten; the letter refers to a possible order for 100 tons of rails to be made with Hay matte:

* * Do not make any test metal till you get new sponge, that old is probably deteriorated, but will do with a mix of fresh for general use. I would take no risk. I think a little tungsten on a test heat would be advisable, if I can get it will make enough for one cast.

A similar reference to the spoiling of the matte in time is the following (Oct. 22, 1880):

As regards your new sponge the carbon and manganese will both evaporate. The only way to make it will be to remelt the sponge in a crucible and pour it into hot spiegel or melt the two together in a crucible.

The statements written by Hay in praise or explanation of his material exhibit in great perfection the wild, meaningless language of the erratic pseudo-scientist, and they are quite sufficient to discredit him and his process completely. The specimen printed in Engineering News of April 14, 1877, is sufficient to demonstrate this.

Hay's rise to fame as a steel expert did not live long. Business would not come. Apparently the rail orders he expected went elsewhere. In the same period he was figuring on further bridges, as shown by a passage from a letter of Hay dated Feb. 19, 1881, referring to a bridge steel specification drawn by C. Shaler Smith:

I think we can fill them. Such metal wants to be high in aluminum for ductility and high in chromium for elasticity and low in carbon to stand water.

An endorsement penciled on the sheet seems to state the essential points of the specification:

Elastic limit 38,000 lbs.
Ductility 15% in 12 diameters.
¼-in. plate heated to cherry red plunged in water at 70° Fah. bend double cold without fracture.

But there is no evidence that Hay steel was used under this specification, and as Mr. Kent says (in the letter already noted) that the process was not used after 1879, the faith of those who brought about its use in the three structures mentioned had probably evaporated.

*See an article on Andrew Kloman's process of rolling bars, with thickened ends as blanks for eyebars, Eng. News, May 17, 1879, p. 157. This contains the passage: "The eyebars used in the construction of the steel bridge over the Missouri River at Glasgow, Mo., were all manufactured by Mr. Kloman by this process, and since then they have been adopted in many other bridge structures throughout the country."

THE WATERPROOFING OF ROAD SURFACES is briefly discussed in a paper by Mr. George W. Manning, Surveyor to the Staines Rural District Council, read before the Incorporated Association of Municipal and County Engineers on May 11, 1910. After seven or eight years' experience with tar spraying and tar painting, the author states that these methods must be regarded as mere apologies which

reduce the dust nuisance during the sometimes dry months of the summer. This dressing, except in isolated cases, does not enter the body of the road at all, and simply churns up into black mud under the traffic when the autumn rains and frosts commence, leaving the pores of the road exposed to the worst action of the winter weather.

As a result of this experience, the author has turned his attention from surface treatment to the introduction of bituminous binder through the mass of the macadam. He recites various experiences with slag and granite when treated in this way. The slag gave satisfactory results until the quality of slag available deteriorated. The broken granite treated in this manner has also given quite satisfactory results. The final conclusion of the paper is that a great obstacle in the way of suitable dust-proof roads is the heavy cost involved in construction and repairs. On this account the author looks forward hopefully to the possible eventual passage of the financial budget which has caused so much political disturbance in England and which has as one of its features a provision calculated by those who drafted the budget to yield a considerable revenue from those who make use of motor vehicles.

THE GERMICIDAL EFFECT OF WATER from coal mines and tannery wheels upon B. typhosus, coli, and Anthracis, has been studied by the State Department of Health of Pennsylvania (Dr. Samuel G. Dixon, Commissioner). We quote the concluding paragraphs of a department bulletin on the subject, as follows:

Mine water will prevent the growth of typhoid bacilli after the lapse of one hour. Mine water will markedly limit the growth of colon bacilli so that they die off progressively and cannot be cultivated after a lapse of 24 hours. The organisms lived for three days but could not be found on the fourth day, in one experiment in which the dilution was high. Spent tan-liquor limits the growth of the typhoid bacillus and causes it to disappear after the sixth hour. Tan-liquor permits the growth of the colon bacillus up to the 24th hour and in one experiment where the dilution was 1-4000 it was found after three days.

As to B. Anthracis, the same may be said as in the case of B. coli, the tan-liquor in general producing a decided diminution in the number of bacteria, in all cases from plating made at once, up to the seventh day, but in no case was there a complete elimination of these micro-organisms from any one of the waters, showing, therefore, that the spores are not especially effected by the tan-liquor in question.

The only inference that can be drawn from the above experiments is that, so far as the risk of the most serious of all water pollutions is concerned, that by the typhoid bacillus and its companion and index, the colon bacillus, and inferentially of the cholera bacillus, which is known to succumb readily to sulphuric acid, the attempt to exclude mine water and spent tan-liquor from streams which may eventually become sources of drinking water would be a mistake. Evidently neither of these organisms can live for any considerable time in water containing these wastes in any appreciable quantity. Especially is this true of that most dangerous and elusive bacillus, that of typhoid fever. Data are not yet available to indicate to what distance from the mine or tannery the protective influence of these wastes will extend. That of the mine water will evidently continue effective to a much greater distance than that of the tannery waste. As the waste is occasionally infected with anthrax spores, it should never be discharged into the streams in an untreated condition.

There has long been an opinion prevalent among those who have studied the health conditions of Philadelphia that the acid condition of the head waters of the Schuylkill River, owing to mine drainage, was an important factor in holding in check the prevalence of typhoid fever in that city.

These results indicate that this opinion had a solid foundation.

Tests of a Locomotive Using Superheated Steam; Atchison Topeka & Santa Fe Railway.

The use of superheated steam for locomotives has been taken up very energetically by the Atchison, Topeka & Santa Fe Ry., and a large number of engines have been and are being equipped. Most of these have superheaters of the tubular drum type invented by Mr. H. W. Jacobs, Assistant Superintendent of Motive Power, the details of construction being modified to suit different types of engines. The first of these superheaters gave such good results in regular service as to warrant consideration of the general application of the device, and before taking the step it was very desirable to have careful tests made of the comparative performance of similar engines (with and without superheaters) operating under similar condition of service. Tests of this kind were made in August, 1909, and the particulars of these are given below.

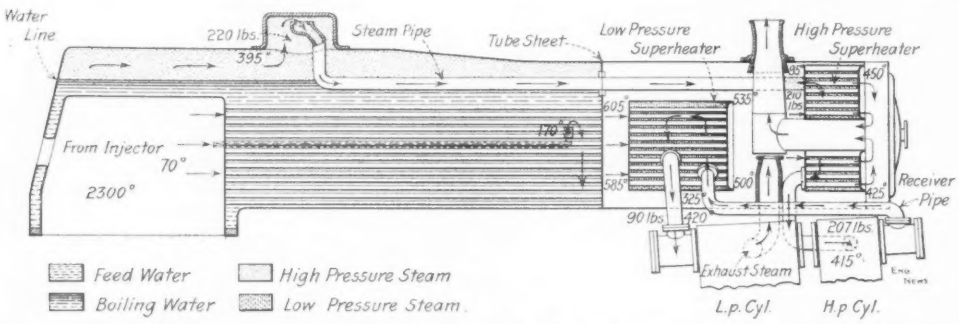


FIG. 1. ARRANGEMENT OF THE JACOBS HIGH AND LOW PRESSURE SUPERHEATERS ON TANDEM-COMPOUND FREIGHT LOCOMOTIVE NO. 901; ATCHISON, TOPEKA & SANTA FE RY.

The engines were four-cylinder tandem-compounds of the 2-10-2 class, used in freight service on a mountain division, and their leading dimensions are given in Table I. The Jacobs superheater was described in our issue of Jan. 27, 1909, and its arrangement upon the test engine is shown in Fig. 1. It consists of two cylindrical drums fitted with tubes, and placed in the extension smokebox. The products of combustion pass through the tubes to reach the front end of the smokebox, and then return through a flue in the forward drum to an uptake pipe leading to the smokestack. The steam from the throttle valve is led to the upper part of the forward (or high pressure) drum and passes down in a circuitous course (by means of baffle plates) over the tubes, escaping then by a pipe to the steam chest of the high-pressure cylinder. The exhaust from this cylinder is delivered to a receiver pipe and discharged in the rear (or low pressure) superheater, where it passes over the tubes and escapes by a pipe to the steam chest of the low-pressure cylinder. The low-pressure exhaust is discharged through a blast nozzle into the base of the uptake pipe mentioned above.

The temperature at the rear part of the smokebox (around the low-pressure superheater) is from 500° to 600° F., but reduced to 420° to 430° in the front end and in the uptake. In the smokebox of the engine without superheater the temperature was 515° to 535° F. This engine had a spark-arrester diaphragm across the smokebox, which was of the extension type.

A pamphlet describing the development and use of superheaters on this road, and also the details of the comparative tests made, has been prepared by Mr. H. B. McFarland, Engineer of Tests of the A., T. & S. F. Ry., under the direction of Mr. W. F. Buck, Superintendent of Motive Power. This is copyright, but we give herewith some abstract of the principal features of interest. The illustrations are reproduced from the pamphlet, and the accompanying tables have been prepared from the records and figures therein given. Elsewhere in this issue we give some further particulars as to the use of superheaters on this railway. With this explanation of the situation and brief description of the superheater as applied to the engine under test, we turn to the report prepared by Mr. McFarland.

Present developments in the use of superheated steam in locomotive performance have led to a great number of tests of such locomotives to determine the lines along which future construction should proceed. Many of these tests have been made with highly superheated steam; others with low degree of superheat. The tests herein recorded relate to the performance of freight locomotives equipped with superheaters designed to give moderate superheat.

Experience with the Baldwin superheater as installed on freight locomotives on the Atchison, Topeka & Santa Fe, Ry. System indicates that economical results may be obtained with a properly designed superheater giving such a moderate degree of superheat as is necessary to reduce cylinder condensation. While considerable virtue has been attributed to a low degree of superheat, yet its value has not been so pronounced as to warrant the equipping of all locomotives on the System with this kind of superheater. Experience indicates that some type of smokebox superheater will give better results, all things considered, than a superheater which requires the deformation of the boiler and a consequent reduction of efficient heating surface in the boiler flues.

In June, 1909, engine No. 901 was turned out of the Topeka shops equipped with a Jacobs high and low-pressure superheater (Fig. 1). This is a tandem-compound locomotive of the 2-10-2 class, and is used for heavy mountain service. From the start this locomotive showed its superiority over other locomotives of same class. It started quicker, hauled a greater tonnage and used less fuel. The superior advantages of moderately superheated steam on this class of power were apparent to all observers. A special point noticeable is that when the cylinder cocks are opened no water drips from them, while on the other locomotives of similar type there is a continual stream of water running from the high and low-pressure cylinder cocks.

It has been generally conceded that superheated steam is of value in passenger locomotives where high speeds are attained, but the economy of using superheated steam with freight locomotives where low speeds are attained has not heretofore been definitely settled. Arrangements were made to make a thorough test of engine 901 operating under ordinary conditions of road service, and to make a similar test of another engine of the same class not equipped with superheater, to get comparative results to determine the efficiency of superheated steam for compound freight locomotives. The installation of superheaters on all classes of locomotives and for all conditions of service is such a big problem on a great system that much importance was given to the tests in order to secure accurate data relative to all conditions of engine performance.

The tests were made on the first district of the New Mexico division, between La Junta, Colo., and Raton, N. M., 105 miles. On account of the mountain grades however, the tonnage rating is different between La Junta and Trinidad from that over Raton Mountain between Trinidad and Raton, where it is customary to use helper engines. Therefore results relative to performance between Trinidad and Raton were omitted. The distance from La Junta to Trinidad is 81.5 miles and in this distance there are 50 miles of an almost constant grade of 59.7 ft. per mile (1.13%), the remaining 31.5 miles having the same average ruling grade but all rolling. From Timpas to Simpson, 32.3 miles, there is an opportunity to make, as nearly as possible, a capacity test of the locomotives, as in this territory there is an almost constant uphill grade. There are, however, a few momentum grades but they are not such as to relieve the engine of drawbar pull.*

The road tests could not, of course, be made under laboratory conditions. They were made in actual mountain service with heavy tonnage trains. The engineman was instructed to make no difference in the general operation of the engine on account of tests. The regular engine crews (who had for a considerable time been assigned to the different engines) were used, so that the results of tests might be more nearly in conformity to actual operations. The conditions of road service do not permit of a constant position of either reverse lever or throttle over the track but require continual changing in position in order to maintain drawbar pulls with long trains and consequent break-in-twos. As a consequence the records show considerable irregularity in performance on account of curves and grades. The average results, however, show considerable regularity in that there is such a correspondence in results recorded and grade conditions as to identify the operation of the engine on any particular portion of the trip. The special importance, then, to be laid on the records is that they contain in detail the history of all changes made and that readings were taken frequently enough to obtain this data.

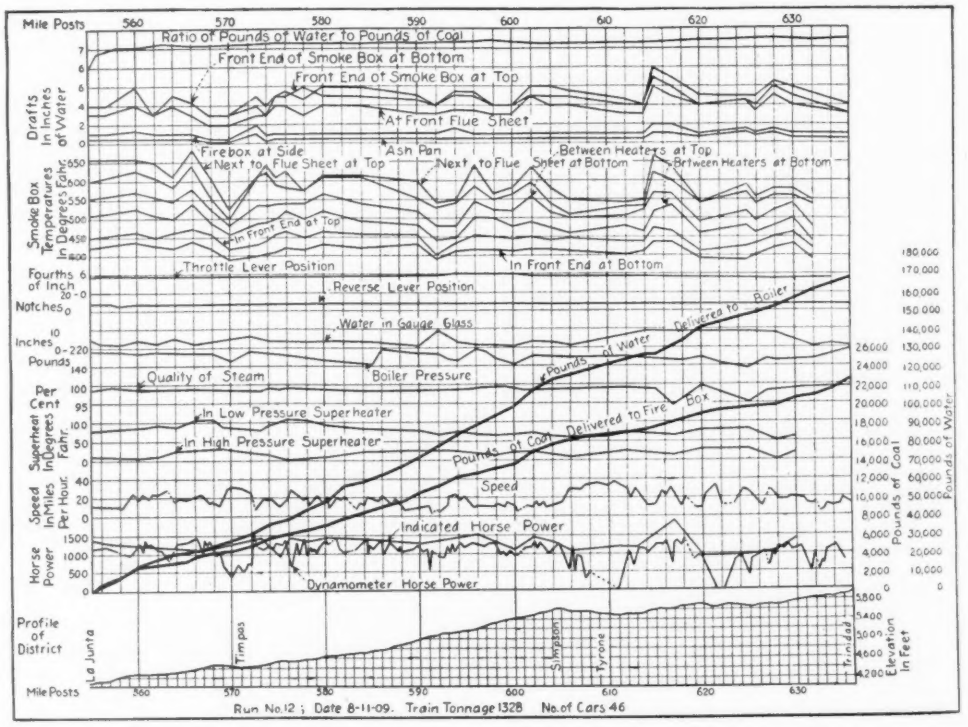


FIG. 2. CHART OF RUN WITH SUPERHEATER LOCOMOTIVE NO. 901 FROM LA JUNTA TO TRINIDAD (RUN NO. 12, AUG. 11, 1909).

The engines of the class under test (2-10-2) at the time of their introduction, eight years ago, and until the advent of heavy Mallet articulated compounds into this country, were the largest locomotives in the world. On account of their single rigid wheelbase they are not applicable to very short curves, but on track where they

*The profile is shown on the accompanying diagrams.—Ed.

can be used give extremely satisfactory service in point of tonnage pulled and economical operation.

They are outside-cylinder tandem-compounds, and operate with a boiler pressure of 220 lbs. Both piston valves on either side of the engine are attached to one stem and are designed to give the same cut-off in both high and low-pressure cylinders. The high-pressure valve has inside admission, the low-pressure outside admission.

The engines have 57-in. drivers and are used in both miscellaneous pusher and heavy freight service on the heavy grades found in that portion of the southwest through which the Santa Fe Ry. runs. In this territory it is necessary to cross five ranges of mountains on which the maximum grades vary from 2 to 3.5%, and on all of these ranges the 2-10-2 type is the prevailing class of freight power. Due to the weight of the heavy reciprocating parts of these engines, they have a limiting speed of 25 m.p.h. Greater speeds, however, may be attained but at an increased expense of engine maintenance.

Of these engines, 70 are used as coal burners and 90 as oil burners. In starting heavy tonnage trains on 3 and 3.5% grades they will exert a drawbar pull of 75,000 lbs. and can maintain a 45,000-lb. drawbar pull at 10 m.p.h. on a 3% grade. These engines were designed for heavy freight service on single track where traffic is heavy and where the main idea is to pull tonnage and make speed. This consideration for speed reduces their rating somewhat from the theoretical rating of that possible in a slow drag train. The actual rating of these engines on through freight trains is as follows:

Grade, per cent.	Tonnage rating.	Grade, per cent.	Tonnage rating.
3.5	540	1.5	1,150
3.0	600	1.0	1,350
2.5	650	0.5	3,300
2.0	950	...	....

No changes were made in the construction of engine 901 at the time of the application of the Jacobs superheater except those necessary in the design of steam pipes and the moving of the front flue sheet back 42 ins. While the shortening of the flues reduced the tube heating surface considerably (as shown by Table 1) it did not prove at all serious in affecting the steaming qualities of the boiler. No changes were made in the valve setting.

Nearly all of the runs were characterized by results that showed the Ind.-HP. was at times less than the drawbar HP. Such results would be impossible to obtain, except on a road test of this character. These results do not indicate, however, that the apparatus was recording improperly but they bring out facts that are characteristic of every-day performance.

A careful study of the dynamometer chart in connection with the profile of the grade and curvature of the track, reveals the fact that the power developed in the cylinders of the engine is often less than the drawbar HP. Just as the engine is on the point of tipping over the grade the whole weight of engine and tender, instead of being moved up the grade by the power developed in the cylinders, is thrown forward and tends to exert an increasing drawbar pull. This sometimes will amount to several thousand pounds and the drawbar pull will increase throughout a considerable portion of the train and the train will accordingly be accelerated unless the engineman is thoroughly familiar with the handling of heavy trains under such conditions. In order to prevent this increase in drawbar pull as well as to permit increase in acceleration until the train is sufficiently over the crest, so that there is no liability of pulling drawbars on account of undue stresses, the engineman shuts off throttle for a short period of time, maintaining normal speed. If at the time he shuts off his throttle indicator cards are taken, they will show power in the cylinders less than that at the drawbar.

On the one side of the crest, the weight of the engine and tender is being moved up the grade and is offering resistance to motion to train; on the other side of the crest the weight of engine and tender, due to the fact that they are running down hill, tends to accelerate motion of train. Due to this fact the determination of points on a territory is an important one in order that characteristic performances and efficiencies that seem reasonable may be obtained.

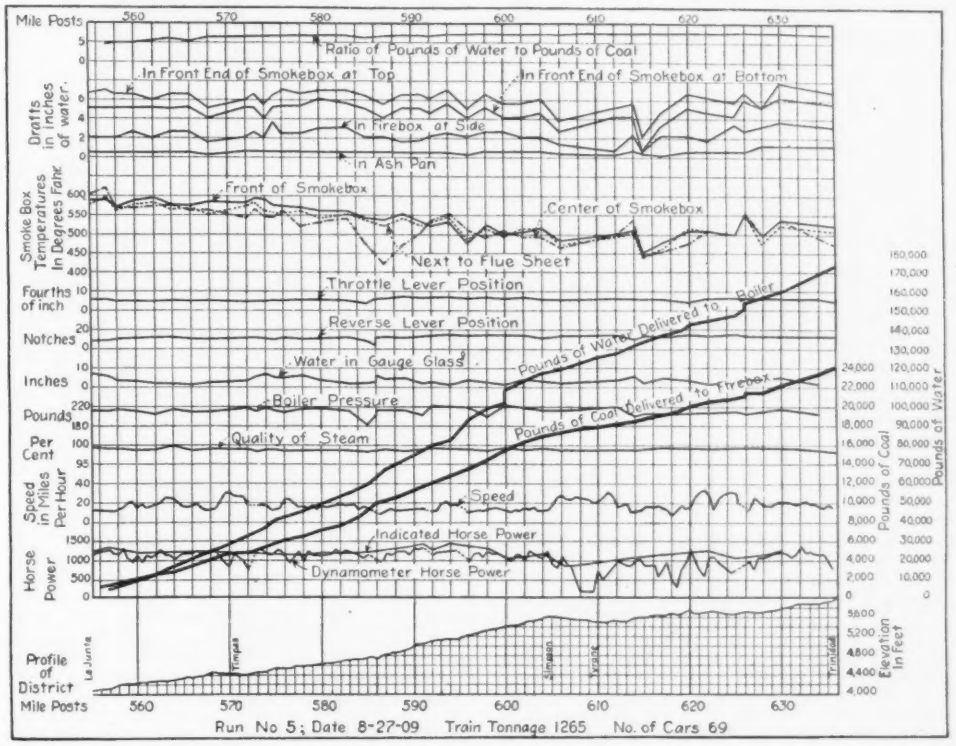


FIG. 3. CHART OF RUN WITH NON-SUPERHEATER LOCOMOTIVE NO. 923 FROM LA JUNTA TO TRINIDAD (RUN NO. 5, AUG. 27, 1909).

Results of Tests.

The report describes the results of the several individual tests. From these we have selected four tests, including one up-grade and one down-grade run with each engine, and the figures of these are compiled in Table II., while in Table III. we have arranged the average results of the tests with both engines. The diagrams and charts given herewith relate to the two up-grade test runs recorded in Table II.

ENGINE 901 (SUPERHEATER); Run No. 12.—All data recorded relative to the performance of the engine on this trip are shown graphically in Fig. 2. Mr. McFarland points out that this chart has been so arranged that it is easy to identify the characteristic performance of the engine on the different grades and under different operating conditions. Maximum and minimum conditions show up very fully. The engine gave a drawbar pull of 39,740 lbs. at 12.7 m.p.h., 32,490 lbs. at 16 m.p.h., and 19,530 lbs. at 26 m.p.h. At milepost 617, the engine showed 1,937 Ind.-HP. at 26 m.p.h. and developed 1,354 drawbar HP. This power was developed under accelerating conditions.

Run No. 13.—The coal consumption per 1,000 ton-miles was the best record obtained on down-grade runs (Table II.). The heat value of the coal used was considerably less than on previous trips. The coal had a theoretical evaporative value of

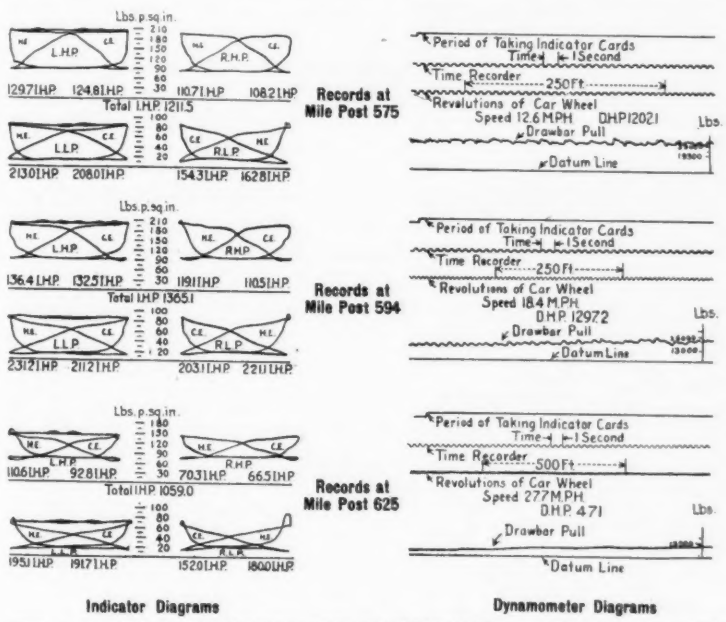


FIG. 4. TYPICAL INDICATOR AND DYNAMOMETER DIAGRAMS FOR RUN NO. 12, WITH SUPERHEATER LOCOMOTIVE.

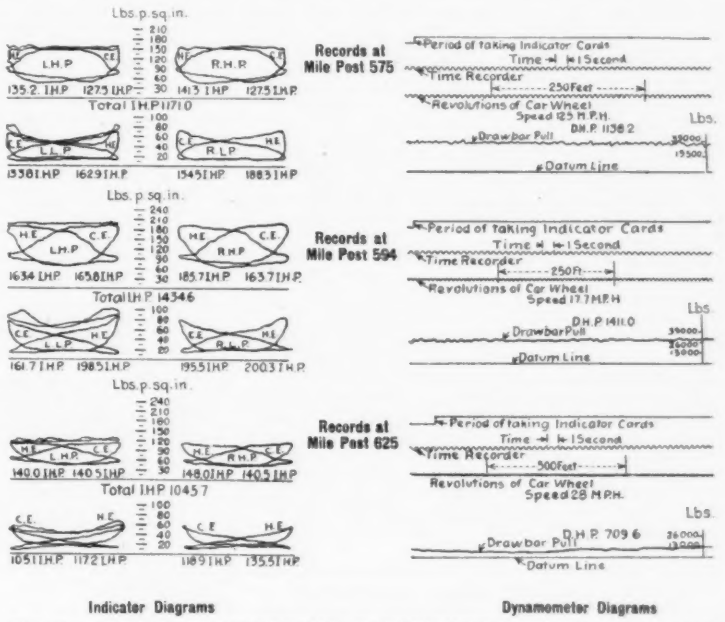


FIG. 5. TYPICAL INDICATOR AND DYNAMOMETER DIAGRAMS FOR RUN NO. 5, WITH NON-SUPERHEATER DIAGRAM.

TABLE I.—DIMENSIONS OF FREIGHT LOCOMOTIVES (2-10-2 CLASS) USED IN SUPERHEATER TESTS; A., T. & S. F. RY.

Engine (Four-Cylinder Tandem-Compound).	901 (with superheater).	923 (without superheater).
Driving wheels (10)	4 ft. 9 ins.	4 ft. 7⅝ ins.
Wheelbase: driving	19 ft. 9 ins.	19 ft. 9 ins.
Engine, total	35 ft. 11 ins.	35 ft. 11 ins.
Engine and tender	66 ft. 0 ins.	66 ft. 0 ins.
Blind tires	Middle (main)	drivers.
Weight on drivers ..lbs.	234,580	234,580
Trucks; (front, 23,420; back, 29,240) "	52,660	52,660
Engine, total "	287,240	287,240
Tender (empty, 68,000 lbs.); loaded "	165,800	165,800
Engine and tender, loaded "	453,040	453,040
Cylinders, high pressure (2)	19 × 32 ins.	19 × 32 ins.
Low pressure (2)	32 × 32 ins.	32 × 32 ins.
Receiver volume: high pressure superheater	33.7 cu. ft.	.....
Low pressure superheater (or receiver No. 923)	34.5 cu. ft.	9 cu. ft.
Valve gear: Stephenson link; piston valves	.....	.....
Ports, steam	1⅝ × 6 ins.	1⅝ × 6 ins.
Ports, exhaust	6 ins.	6 ins.
Valve travel, max.	5¼ ins.	5¼ ins.
Lap inside (negative), high pressure	¼-in.	¼-in.
Lap inside (negative), low pressure	⅜-in.	⅜-in.
Lap outside, high pressure	⅞-in.	⅞-in.
Lap outside, low pressure	¾-in.	¾-in.
Lead, (full gear), line and line	.....	.....
Eccentrics, throw	6 ins.	6 ins.
Boiler (wagon top); diameter first ring	6 ft. 9 ins.	6 ft. 9 ins.
Firebox (wide, radial stay)	104 × 78 ins.	104 × 78 ins.
Depth, front and back	74½ & 72½ ins.	74½ & 72½ ins.
Tubes, No.	391	391
Diameter, outside	2¼-ins.	2¼ ins.
Length over tube plates	16 ft. 5 ins.	19 ft. 11 ins.
Superheater H. press.	L. press.	.....
Diameter, outside 70 ins.	66 ins.	.....
Distance between sheets 30.25 ins.	53.13 ins.	.....
Capacity, cu. ft. 33.70 ins.	34.50 ins.	.....
Central flue 20.0 ins.	5.67 ins.	.....
Tubes, No. 746	691	.....
Diam. outside 1.5 ins.	1.5 ins.	.....
Total superheater surface; sq. ft. 784	1,227	.....
Heating surface, total sq. ft.	3,582	4,299
Grate area, sq. ft.	58.5	58.5
Ratio of total heat. s. to grate area	61.24	73.84
Capacity of tender tank, gallons	8,500	8,500
Capacity of coal space, lbs.	27,000	27,000
Tractive force, lbs.	62,800	62,800

13.25 lbs. of water per pound of coal, so that the efficiency of the boiler was 69%.

ENGINE 923 (NO SUPERHEATER); Run No. 5.—The records of this trip are shown in Fig. 3 and Table II. The engine gave a drawbar pull of 34,220 lbs. at 11.8 m.p.h., 27,680 lbs. at 15.6 m.p.h., and 24,540 lbs. at 19.6 m.p.h.

Run No. 2.—Two delays occurred on this down-grade trip on account of breaking of train equipment: 1 hour due to a broken knuckle, 20 minutes to a drawbar pulled out. During these periods 600 lbs. of coal were fired.

COMPARISON OF THE TESTS.—A general comparison of the results is shown by the third column in Table III., but some of the points of advantage of the engine with superheater may be noted: (1) it shows an average saving of 20.8% in coal per 1,000 ton-miles and a total average saving in fuel of 13.3%; (2) it has a greater rate of combustion of fuel, with a lighter draft on the fuel bed and less total resistance to flow of gases through boiler and superheater tubes; (3) it shows an increase in evaporation per hour of 8.7%, or 30.8% per sq. ft. of heating surface per hour; (4) it shows an increase of 7% in the ratio of water to coal.

On the heavy grade section between Timpas and Simpson, the superheater engine showed a fuel saving of 19.6% (or 59.6 lbs. per 1,000 ton-miles), with 4.7% less fuel per hour per sq. ft. of grate. On the down-grade runs, the saving in fuel was 11.5% per 1,000 ton miles, or 14.5% per trip.

Indicator Cards from Superheater Engines.

The application of a superheater between the high and low-pressure cylinders of a tandem-compound locomotive affords an opportunity for studying the effects of a large receiver volume on the distribution of Ind.-HP. between the high and low-pressure cylinders for various engine speeds.

On the non-superheater locomotive, the receiver volume between the high and low-pressure cylinders is very small, 6 cu. ft.; furthermore, the cylinder receivers on each side of the locomotive are entirely separate. The high-pressure exhaust line follows closely the low-pressure admission line, and with equal ratios of cut-off the ratio of Ind.-HP. in the two cylinders is nearly unity, averaging 1 to 1.21 for the entire runs. Any increase in speed tends to bring the ratio closer to unity, so that both high and low-pressure cylinders develop nearly the same amount of power. Due to small receiver volume, the receiver pressure fluctuates greatly and records with distinctness the characteristic events of the stroke.

On the superheater locomotive, the receiver between the high and low pressure cylinders has a capacity of 34.5 cu. ft. Both high and low pressure cylinders exhaust into the one receiver at different quarters of the stroke, and thereby maintain a comparatively high receiver pressure. With the aid of the starting valve the pressure is raised to a maximum in one stroke. As soon as this pressure is attained, the back pressure line of the high-pressure cylinders becomes a straight line parallel to the atmospheric line. While its height depends entirely on how hard the engine is working, yet it is never slanted downward nor does it follow the low-pressure admission line as in the other locomotive.

Both high pressure cylinders exhaust at different times into a common receiver. Due to the large volume of this receiver, the admission line on the low-pressure is maintained more nearly horizontal than on the engine without large receiver volume. The receiver is a superheater and also serves to re-evaporate water condensed in the high-pressure cylinders, thereby greatly increasing the volume of the exhaust steam from the cylinders as well as making a further increase in volume by superheating. Accordingly there is always a tendency for an increase in the back-pressure in the high-pressure cylinders. These conditions cause an increase of pressure in the high-pressure cylinder, reduce the mean effective pressure in the high and increase it in the low pressure cylinders, thereby increasing the horse-power ratio between the two cylinders from 1 to 1.98 for the average of the entire runs. The lower the speed the more even the division of power. The higher the speed the greater the ratio in favor of the low-pressure cylinder.

This distribution of power made engine 901 (with superheater) slightly more powerful at slow and average speeds than engine 923. At high speeds, however, the difference in power was less perceptible. The gain in horse-power in the low-pressure cylinder more than offset the loss in the high-pressure cylinder, both at high and low speeds.

The influence of a large receiver on starting is most important. If the starting valve is not sufficiently large or there is not a by-pass allowing steam at boiler pressure to enter the receiver through a quick opening valve the engine will be so slow in starting that the insufficient engine momentum acquired will be inadequate to start a heavy train. On this engine the simpling or starting valve was large enough so that the large volume receiver was quickly filled with steam at a good pressure. The first low pressure cards taken at starting showed from 20 to 25% more horse-power than cards immediately following. This condition for starting made the engine exceptionally powerful, so that when necessary to stop for switching or for section men on steep grades or on bad curves, there was no great difficulty in starting the train. Other engines of the class under such conditions of stopping usually have to back up and run for the grades.

The indicator cards of engine 901, Fig. 4, are such as should be expected at slow speeds. At high speeds, however, there was considerable negative work in the high pressure cylinders, part of which was due to lack of lead and excessive compression and part to the way in which both high-pressure cylinders exhausted at different times into the one receiver. The indicator cards for engine 923 (without superheater), Fig. 5, are typical cards for engines of this design, though the lead on cards at slow speed does not seem in all cases to be sufficient.

Firebox Arch Brick.

Both engines were equipped with four 3-in. arch tubes placed in the firebox in such a manner as to allow the ready application of arch brick equipment. Locomotives of this type are subjected to very high temperatures in the firebox, and when they are not most carefully drafted draw harder on the lower and central flues, thereby putting undue internal strains on the top ones. The gases are also drawn directly into the flues many times before combustion is complete, and so escape from the stack at a high temperature. The brick arches that are applied change the drafting in the firebox. The arch becomes white hot, thereby increasing the box temperature and improving the combustion of the gases. The drafts in the lower flues are reduced and the middle and upper flues give more effective service.

The comparative performance of engines 901 and 923 with and without arch shows a decided saving for the arch in pounds of coal per thousand gross ton miles; this saving amounted to 29.6 lbs. (or 12.8%) for engine 901 (with superheater) and 62.2 lbs. (or 19.6%) for engine 923. Unfortunately, only one run per engine was made without the arch, and with such a limited comparison there is too great a possibility of variation to draw broad final conclusions as to efficiency of arch brick equipment. Evaporative efficiency appears to be greater without the arch for engine 901, but on this run the boiler was not worked to its maximum capacity and some such a result might be expected. Neither engine steamed as freely or carried as constant boiler pressure without the arches as with them, and generally the arches seemed to make maximum working condition more simple.

Conclusions.

In order to make valuable deductions from the results of a road test of locomotives as far as fuel, water and special performance is concerned, it is necessary to compare performances of the same engine or engines of the same class with different equipment. There is ample opportunity to compare the data obtained from test of simple engine with superheater with the results of performance of tests of compound engines with and without superheater. Great care, however, must be taken in making such comparisons that proper consideration is taken for all factors that influence results. The results of the test may be stated briefly as follows:

1. The average coal consumption per 1,000 gross ton-miles over entire run was 240.1 lbs.; for longest heavy working 292.7 lbs.

2. The coal burned per hour per sq. ft. of grate area

TABLE II.—SUMMARY OF RESULTS WITH INDIVIDUAL RUNS BY ENGINES WITH AND WITHOUT SUPERHEATER.

	La Junta to Trinidad (up-grade).		Trinidad to La Junta (down-grade).	
Engine	901 (superh.).	923	901 (superh.).	923
Run	No. 12	No. 5	No. 13	No. 2
Date, 1909	Aug. 11	Aug. 27	Aug. 13	Aug. 22
Train tonnage	1,328	1,265	3,166	3,171
No. of cars	46	69	59	62
Time, total	7 h. 2 m.	6 h. 14 m.	5 h. 45 m.	7 h. 42 m.
Time delayed	1 h. 44 m.	0 h. 29 m.	1 h. 40 m.	3 h. 0 m.
Time, running	5 h. 18 m.	5 h. 45 m.	4 h. 5 m.	4 h. 42 m.
Coal fired ..lbs.	22,048	24,618	8,300	11,370
Water to boiler ..lbs.	158,355	169,713	61,801	74,340
Equiv. evap. from and at 212° ..lbs.	8.22	7.82	8.62	7.25
Do. allowing for superheater* ..lbs.	8.81	.....	9.15	.....
Boiler efficiency*	65.80%	52.2%	69%	51.4%
Boiler efficiency; Timpas to Simpson	64.80%	56.3%	.....	.....
Coal per 1,000 ton-miles, for run ..lbs.	203.8	238.8	32.2	44.1
Do., Timpas to Simpson ..lbs.	250.0	292.9	.....	.....
Maximum temperature, high-pressure steam	422°	.....	408°	.....
Maximum temperature, low-pressure steam	432°	.....	439°	.....
Maximum superheat, high-pressure steam	35°	.....	32°	.....
Maximum superheat, low-pressure steam	105°	.....	110°	.....
Drawbar pull, lbs.	32,490 at 16 m.p.h.	34,220 at 11.8 m.p.h.	.....	.....
Drawbar pull, lbs	19,530 at 26 m.p.h.	24,540 at 19.6 m.p.h.	.....	.....

*Giving credit for heat regained from waste gases in superheating steam.

was 62.1 lbs., and per sq. ft. of heating surface 1.76-lb.

3. The equivalent evaporation was 31,409 lbs. of water per hour, 6.62 lbs. of water per sq. ft. of heating surface per hour, and 9.98 lbs. of water per pound of coal.

4. The boiler efficiency was less for trip than for heavy grade performance, being 66.7% for trip and 71.0% from Timpas to Simpson.

5. The superheaters transmitted heat to steam in proportions to the water evaporated, thereby maintaining the superheat very constant for different rates of engine performance.

6. The steam temperature was raised almost equally in each of the superheater drums.

7. The rolling resistance of engine and machine friction amounted to 17.2%.

8. The locomotive efficiency was 3.98%.

TABLE III.—AVERAGE OF RESULTS PER TRIP FOR UP-GRADE TRIPS FROM LA JUNTA TO TRINIDAD.

	No. 901 (with superheater).	No. 923 (without superheater).	In favor of No. 901.
Train tonnage	1,333	1,220	+113
No. of cars	48	67	— 19
Time, total	6 h. 34 m.	4 h. 46 m.	.....
Time, running	6 h. 14 m.	5 h. 43 m.	.....
Speed, m.p.h.	17.07	14.23	+2.84
1,000 gross-ton-miles	108.5	99.4	.....
Coal per 1,000 ton-miles....lbs.	202.1	255.0	20.8%
Fuel fired....lbs.	21,940	25,300	13.3%
Coal per hour, total time....lbs.	3,342	4,055	—713
Running time....lbs.	4,650	4,415	+235
Per sq. ft. grate....lbs.	78.60	75.40	+3.20
Per sq. ft. heating surface....lbs.	1.28	1.02	+0.26
Draft, top of front end (ins. of water)	5.4	5.8	.....
Water delivered to boiler....lbs.	166,919	173,932	—7,013
Temperature of feed water	73°	72°	.....
Steam per hour....lbs.	.....	.....	.....
From boiler, moist....lbs.	31,790	29,413	+2,377
To pumps, etc....lbs.	946	1,069	—123
To cylinders....lbs.	30,844	28,344	+2,500
Per sq. ft. heating surface....lbs.	8.57	6.51	+2.06
Pressure, lbs. per sq. in.; Boiler	189	202	—13
High pressure superheater	182	...	.....
Low pressure superheater	82.3	...	.....
Steam, quality, at dome	98.9%	98.9	.....
At high pressure exhaust	96.9%	...	.....
Temperature of steam leaving high pressure superheater	403.3°	...	.....
Leaving low pressure superheater	416.3°	...	.....
Superheat (F.); leaving high pressure superheater	22.6°	...	.....
Leaving low pressure superheater	93.3°	...	.....
Coal, B. T. U. per lb.	12,992	13,488	—496
Dry fired....lbs.	23,142	25,863	—2,721
Combustible fired....lbs.	20,124	22,722	—2,721
Ash fired....lbs.	3,082	3,138	—56
Ashes removed....lbs.	1,941	3,218	—1,277
Consumption, lbs. per hour	.....	.....	.....
Dry coal	4,416	4,366	+50
Combustible	3,842	3,904	—62
Dry coal per sq. ft. grate	75.5	74.6	+0.9
Combustible per sq. ft. grate	65.7	66.7	—1.0
Ratio, total water to coal	7.17	6.70	+7%
Equiv. evap. from and at 212° F.	.....	.....	.....
Per hour at dome	36,675	33,724	+8.7%
Per hour per sq. ft. heat. surf.	10.23	7.81	+30.8%
Per lb. of dry coal	8.32	7.72	+7.8%
Per lb. of combustible	9.57	8.79	+8.9%
Per lb. of dry coal*	8.89	....	+15.0%
Per lb. of combustible*	9.73	....	....
Ind. HP.; high pressure cylinders	416	542	—126
Low pressure cylinders	846	643	+203
All cylinders	1,262	1,185	+77
Drawbar pull....lbs.	24,705	24,168	+537
Drawbar HP.	1,001	970	+31
Machine friction HP.	261	214	+47
Machine efficiency	79.3%	81.9%	—2.6
Locomotive efficiency	4.5%	4.2%	+0.3
Boiler HP.	1,135	978	+157
Boiler efficiency	65.9	53.5	+12.4%

*Allowing for heat imparted to superheaters.

Steam Superheaters for Locomotives; Atchison, Topeka & Santa Fe Ry.

By H. B. McFARLAND.*

Introduction.†

Superheated steam is receiving a great deal of attention on the part of locomotive builders and railway officials. The subject is one of great importance to all motive power officials. The time is ripe for an aggressive railway to determine whether or not superheated steam shall be used on different classes of power. The matters of fuel economy, of reduced cost of repairs and maintenance, of increased speed and hauling capacity, of decreased time on road, of simplicity in mechanical construction, of low cost in equipment, and of adaptability of a type of superheater to all classes of power, all come up for consideration in final decision.

Many types of superheaters have been tried, some have been greatly complicated, some have proved highly economical, some have had their efficiency destroyed on account of mechanical and lubricating defects. Some have proved to be merely steam dryers, yet even in this capacity have proved very satisfactory, giving such gains in fuel economy and increased serviceability of engines as to warrant most careful investigation and test of superheaters with a moderate degree of superheat for different classes of power and for different kinds of service.

A critical knowledge of the art of superheating, records of performance of the different types of locomotives with superheaters in service in this and in foreign countries, consideration for maximum efficiency with minimum cost, were factors in deciding that the type of superheater to give ultimate satisfaction would be a smokebox, tubular superheater, so proportioned as to deliver steam to the cylinder at a temperature not to exceed 450°. Such a superheater, giving not over 100° of superheat, may be known as one giving a moderate degree of superheat.

The design of a superheater, involving all the above points, as well as being adaptable to simple and compound engines, was worked out by Mr. H. W. Jacobs, Assistant Superintendent of Motive Power. The first superheater was applied to a simple engine in freight service under conditions met on the road; comparative results were to be determined by testing a similar engine without superheater equipment over the same territory. While fuel economy was to be considered the important point to be determined, yet, at the same time, it was decided to make a thorough test, obtaining data to show the complete performance of the locomotives. With this end in view, the engines were equipped with special apparatus for test record. The results were so satisfactory as to warrant the equipping of 50 new 4-4-2 and 30 new 4-6-2 passenger engines with this type of superheater. Later results of service performance and careful tests on our four new Mallet engines warrant the equipping of 40 new Mallet freight engines with Buck-Jacobs type superheaters. Moreover, there are many installations of superheaters being made on locomotives as they go through the shops for general overhauling.

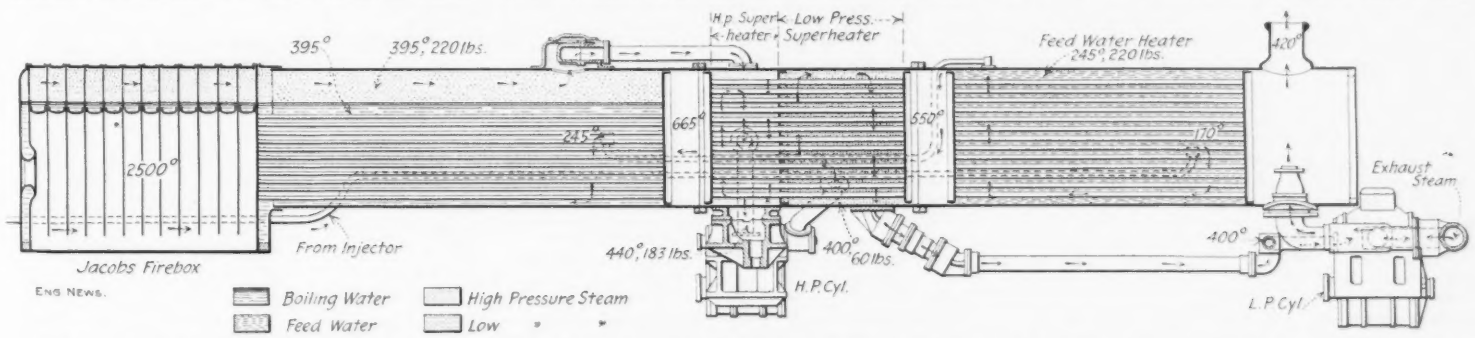


FIG. 1. BOILER OF MALLET ENGINE EQUIPPED WITH JACOBS FIRE BOX, BUCK-JACOBS SUPERHEATER AND TUBULAR FEED-WATER HEATER; ATCHISON, TOPEKA & SANTA FE RY.

Superheaters.

A superheater is a device for applying additional heat to the steam after it has been evaporated by the boiler. The heat thus imparted has the effect of changing the properties of the steam so that upon expansion it obeys the laws of a perfect gas until such an amount of heat is extracted from it by conduction or by work as to cause it to return to a saturated state. Under the usual conditions of operation, the effect of a superheater is to increase the temperature and volume of the steam without increasing its pressure. The thermal advantages obtained from the use of superheated steam are as follows:

(1) At higher temperatures it behaves nearly like a gas, and considerable amount of heat may be extracted before any portion will condense.

(2) The volume of superheated steam increases nearly directly in proportion to rise in temperature, and for the same cut-off in the cylinder the weight of steam required is less with superheated than with saturated steam of the same pressure.

(3) It has greatly reduced thermal conductivity as compared with saturated steam and, therefore, the heat absorbed by the cylinder walls becomes a fraction only of what it would be otherwise.

It has been found, experimentally, that for each per cent. of wetness of steam at cut-off using saturated steam, it requires 7.5° of superheat to prevent any condensation up to that point. Thus, if 25% of the steam were condensed at the point of cut-off, in order to have dry steam at that cut-off, 187.5° of superheat will be required in the steam entering the cylinder.

The problem in the construction of a practical superheater is manifold: (1) It must not overheat locally so as to weaken the metal and give way. (2) It must bring the steam into intimate contact with the superheating walls, as steam is a poor conductor of heat, and should take up the superheat by direct contact with these hot metal surfaces. The steam should, therefore, flow in thin streams and be thoroughly intermixed in its flow. (3) It must be simple to maintain. (4) It should be moderate in first cost. (5) It should have reasonable length of life. (6) It should not obstruct the flow of gases of combustion in such a way as to interfere with the draft or decrease the boiler efficiency.

With reference to the use of superheating in connection with locomotives. There have been two schools of practice: the one advocating low superheat, the other high superheat. The chief disadvantage of low superheat

*Engineer of Tests, Atchison, Topeka & Santa Fe Ry. This article is an abstract of a report (copyright by Mr. McFarland) issued in pamphlet form by the Mechanical Department of the railway. A statement in the report shows 110 simple engines and 34 compound engines on this line equipped with superheaters, as follows: Baldwin superheater, 48 simple, 1 compound; Jacobs superheater, 62 simple, 29 compounds; Buck superheater, 4 compounds.—Ed.

†By W. F. Buck, Superintendent of Motive Power, Atchison, Topeka & Santa Fe Ry., Chicago.

is that it does not, in any appreciable degree, eliminate cylinder condensation occurring during admission and expansion of steam in locomotive cylinders.

The principal disadvantages of high superheat are as follows: (1) The difficulty of locating the superheater in the path of combustion gases sufficiently to attain the degree of superheat required. This, apparently, can be satisfactorily attained only by building the superheater as an integral part of the boiler. This construction makes a high initial cost and is not adaptable to the conversion of the superheater engines already in service. (2) Cylinder castings have to be specially designed, as well as pistons, piston rods, and valves. (3) Proper lubrication is accomplished with great difficulty. (4) Draft, temperature control, handling of throttle and valve gear are required to be more exact. (5) The danger from burning out superheater is great.

In endeavoring to avoid the faults of superheaters giving a high degree of superheat, there has been developed a superheater more effective and more economical than the low degree superheater. Such a superheater gives 100° of superheat, or thereabouts, and insures that steam enters the cylinders at a temperature not greater than 450°. This temperature is sufficiently low so that the superheated steam does not have a deteriorating effect upon the cast iron with which it comes in contact and is not too high in temperature to cause trouble from lubrication.

Superheaters, as applied to locomotives, may be divided into four classes as regards their location: (1) firebox superheater; (2) superheater located in barrel of boiler; (3) smoke tube superheater, replacing portion of boiler flues; (4) front end superheater, located in smokebox.

1. FIREBOX SUPERHEATERS.—There are no good designs of this type. A few attempts have been made to place a superheater in the firebox, but the temperatures are so intense that the metal will not stand up under them, and the designs have been abandoned.

2. SUPERHEATER IN BOILER BARREL.—The simplest design is the Pielock.* It consists of a compartment about in the center of the boiler, through which the boiler flues pass and which is filled with steam on its way to the throttle. The boiler flues are enlarged where they pass through the tube sheets of the superheater and are expanded to insure a good joint. In this design there is no added trouble in keeping the flues clean, as is experienced in the smoke-tube types. A great disadvantage of this type is the fact that it is very difficult to detect a leak in the superheater and to repair same after detection.

3. SMOKE-TUBE SUPERHEATERS.—The general arrangement is as follows: In the top part of the boiler a number of tubes about 5 ins. diameter are introduced, connecting the two flue sheets and acting as ordinary flues. Their number varies according to the size of the engine, usually 25 or 30 being enough. Inside of these flues the superheater tubes are placed. The arrangement of these tubes varies in the different designs, but usually four tubes arranged in pairs are contained in one larger flue extending to within about 3 ft. of the back flue sheet. Each pair of the superheater tubes is connected at the end near the firebox by a casting, thus making a continuous pipe and allowing a flow of steam through one tube and back through the other. One end of such a pair is connected to the saturated steam header in the front end and the other end is connected to the superheater header, also in the front end. In Schmidt's* latest design all of the four tubes are connected into one superheater element, and the steam makes a double loop in its travel from the saturated to the superheated steam header. Thus, steam from the dry pipes enters the saturated steam header, passes through the superheater tubes of the superheated steam header and from there to the cylinders. A damper is arranged automatically to shut off the gases from the superheater tubes when no steam is in the cylinders.

Max Tolz has designed a smoke-tube superheater which eliminates some of the defects of the ordinary designs. In place of the usual round superheater tube, he uses one that is oval in shape. This accomplishes three things: (1) it presents the steam to the hot sides of the tubes in a sheet, thus heating the steam quicker; (2) it leaves more room in the flue for the passage of gases, and also makes the cleaning and blowing out of the flue much easier; (3) it increases the velocity of the steam through the superheater.

Another interesting feature of this design is the fact that the throttle is in the front end and the steam is controlled after it has been superheated and not before. This arrangement does away with the need of dampers to protect the superheating tubes and prevents them from being burned out, for in this design there is always steam in the superheater. On top of the throttle is a pipe in which is a valve which opens when the valve is shut off and allows a circulation of steam from the superheater back of the boiler.

Other designs of this type, such as the Cole and Vaughn-Horsey,* resemble the Schmidt type very closely, differing only in detailed arrangement of the headers and steam tubes, designed to facilitate cleaning, inspection, repairing, and to obviate leaks.

These superheaters aim to attain from 200° to over 300° F. of superheat, but do it at the expense of the boiler heating surface and with a large first cost in modifying boiler construction and difficulties in later operation and maintenance, as well as complication in handling parts of the locomotive, inadvisable in American practice.

4.—SMOKEBOX SUPERHEATERS.—Various engineers have designed and constructed from time to time superheaters adapted to be placed in the smokebox. In the 70's, the Burlington Ry. tried this, and Wilhelm Schmidt early experimented with this design. Some of these were in the form of a short horizontal fire-tube boiler placed in the front end. Others were in the form of coils or banks of steam tubes between the headers and placed in the front end. From various causes these did not prove sufficiently satisfactory to persist as a type for present-day practice, owing chiefly, it must be presumed, to leakage of joints or tube ends and to the great difficulty in keeping up sufficient draft.

Two notable exceptions must, however, be made to this general statement, namely, the Baldwin† smoke-box superheater, which has been working practically for over four years, and the new Jacobs fire-tube front-end superheater. The former was first applied to a 2:10:2 engine, and while the average superheat was but a few degrees, acting therefore merely as a steam drier, the results in fuel economy and in increased serviceability of the engine were so marked as to demonstrate the value of even a very low degree of superheat for locomotive practice. The superheater consists of two sections, one on each side of the smokebox. Each section is composed of a top and bottom heavy cast-steel header connected by curved steam tubes.

This Baldwin superheater has later been applied to a number of new 2:8:0 and 4:6:2 engines, as well as to several converted engines in pusher or helper service. The average superheat obtained is from 30 to 40° and the general performance of these engines has been improved, as compared with engines of the same class not equipped with superheaters. The steam pressure carried ranges from 155 to 165 lbs., and this reduction from 225 lbs. has resulted in a greatly reduced maintenance cost of the boiler. Of course, this type of superheater is subject to great wear on the tubes from the impinging cinders, which have a sand-blast effect. This circumstance increases the maintenance cost.

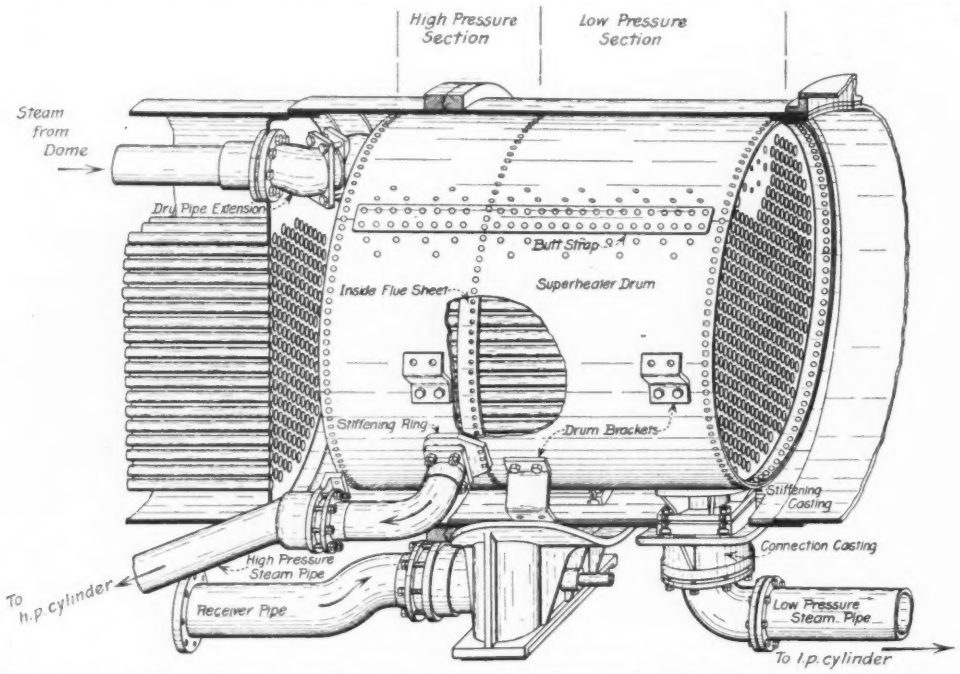


FIG. 2. CONSTRUCTION OF THE BUCK-JACOBS SUPERHEATER FOR LOCOMOTIVES OF THE ATCHISON, TOPEKA & SANTA FE RY.

Jacobs Superheater.*

The Jacobs superheater is of the smokebox fire-tube type and of such design that its application can be readily made to locomotives of the usual type without radical changes to the boiler or front end. The principal feature in its operation is the utilization of waste heat in the combustion gases without a sacrifice of effective heating surface in the boiler. It consists of two steel drums, fitted with a series of horizontal fire tubes between the heads and with steam pipe connections. In the early stages of development, considerable experimental work was carried on to determine the diameter of fire tube giving most satisfactory results, and brought out very strongly, the superiority of the 2¼-in. tube.

The rear drum is made oval in cross-section to provide room for passage of dry pipe extension to the front drum and is placed directly before the front flue sheet of the boiler. The forward drum of the superheater is circular in cross-section and placed just ahead of the exhaust pots. For facilitating repair work on boiler tubes, the rear drum is placed about 24 ins. ahead of the front flue sheet and a manhole, provided in the bottom of the smokebox, gives access for a boilermaker. A 20-in. return flue in the front drum and a 6-in. central flue in the rear drum are lined up so that leaky or defective flues may be cut out of the boiler and removed through the front end without the necessity of taking out the superheaters.

The rear superheater drum, situated as it is, almost immediately in front of the front flue sheet, is exposed to high gas temperatures, subjecting the tubes to severe stresses through expansion and contraction. Under ordinary boiler construction this would result in a constant source of trouble through leaking. Under the method of construction followed with the Jacobs superheater, however, trouble from this source is reduced to a minimum. The tubes in the rear drum of the superheater are inserted without copper ferrules, then rolled and expanded, after which they are welded at both ends by either the autogenous or electric method, thus insuring perfect and permanent joints. It has not been found necessary to weld the tubes in the front drum, as the temperatures of the surrounding gases are considerably lower than those surrounding the rear drum and the stresses are correspondingly less severe. These tubes are merely rolled, expanded and beaded, similar to common practice with boiler flues.

After the gases pass through the rear drum (and are partially deflected) they travel forward through the tubes of the front drum and are drawn back through the central return flue in the front drum to the petticoat pipe and out the stack. This is a radical departure in drafting locomotives, as it does away with the diaphragm and netting, the draft being very direct and also pulling on the fire much more evenly, thus obtaining more complete combustion and more efficient evaporation.

EXHAUST AND DRAFT.—The construction of this superheater entirely changes the front end drafting. In non-superheating locomotives, the sparks and cinders drawn through the boiler flues are caught, broken up and for the most part extinguished before leaving the stack, by striking the front end netting and baffle plate. The petticoat pipe regulates the gas current and tends to aid in distributing the draft more evenly through all the flues. Any adjustment of this pipe, either up or down, is apparent in a coal burning engine by the change in the firebox. Such a change in an oil burner engine is shown by a changed steaming efficiency or variation in boiler pressure.

There is no netting or baffle plate in the locomotive equipped with a Jacobs superheater. The petticoat pipe is only a return flue or concentration tube for the gases. Cinders and sparks strike against the two drums, are whirled around the front of the front drum and by the time they leave the stack are extinguished. Further there are not so many cinders drawn through the flues as in other locomotives. The sharp high peaks of draft

*Engineering News, Nov. 24, 1904, and June 22, 1905.

*Engineering News, June 22, 1905; Nov. 23, 1905; April 23, 1906; Aug. 23, 1906.

†Engineering News, April 20, 1909.

*Engineering News, Jan. 27, 1910, and May 12, 1910. For simple engines there is a single drum, placed at the front end of the smokebox.

noticed in most fireboxes are not present. The draft is more constant, and neither as many or as large cinders are lifted high enough to be drawn through the flues.

Engine 901 (with superheater) required a slightly smaller nozzle than the 923 (without superheater).* Engine 901 had a 5⅝-in. nozzle and engine 923 a 5¾-in., or ⅛-in. in favor of engine 923. The back pressure in any locomotive cylinder depends both on the speed and on the exhaust nozzle diameter; the larger the exhaust nozzle, the smaller the smokebox and firebox drafts. It is therefore important in applying front end superheaters to make their construction such that they are self cleaning with nozzle large enough so that the cylinder back pressure is not greater than in other locomotives.

The indicator cards taken on both engines show that the nozzle can be varied ¼-in. in diameter and not affect the back presure to any constant amount. In the case of engines 901 and 923, it is impossible to tell from the cards which had the larger nozzle, while in the general average the 901 shows a slightly smaller back pressure than the 923.

It can be said, therefore, that when properly adjusted the Jacobs smokebox superheater for engines in freight service assures no live cinders from the stack, and is self-cleaning with exhaust nozzle and cylinder back pressure similar to any non-superheater engine.

Buck-Jacobs Superheater.

A later design known as the Buck type has been applied to four new Mallet locomotives. This type consists of one steel shell for high and low pressure superheaters with a dividing partition or third head which serves to separate the high pressure and low pressure section. The arrangement is the reverse of that of the Jacobs superheater. The high pressure section is the rear section and is about half the length of the forward or low pressure section. With this design it is desired to take advantage of the initial high temperatures of the gases with a narrow high pressure superheater and by increasing the length of the low pressure superheater to obtain relative high results from this section.

Since the application of the Buck superheater several improvements in design have been adopted. The new superheater, known as the Buck-Jacobs type with outside steam pipe connections, applied to the new Mallet engines now being constructed at the Baldwin Locomotive Works, will not be a separate drum. As shown in Figs. 1 and 2, its three heads will be riveted to the boiler shell and all of the steam pipes will be outside pipes, readily accessible and easy of application. By this method it is intended to make the superheater as much a part of the boiler as is the feed water heater. Such a construction offers only a minimum obstruction to the gases, cinders and sparks. This design will increase the available tube superheating surface and will also increase the steam temperatures. The 40 new coal burning Mallet engines will be so equipped, as well as 20 new 4:4:2 and 12 new 4:6:2 type engines.

The design is such that the question of "moderate superheating" for both high and low pressure cylinders in Mallet locomotives is greatly simplified. The double superheater is placed just ahead of the end of the boiler flues, and behind the feed water heater, with manholes on the top of the boiler and sufficient space at each end to permit a boilermaker to enter and work on or remove leaky or defective flues. In this type of superheater, the waste combustion gases pass through the superheater tubes uninterrupted and then through the feed-water heater tubes to the stack.

When the main throttle is opened, the steam flows from the boiler through the dry-pipe extension to the rear or high pressure section of the superheater drum. It circulates over tubes between baffle plates and passes from the bottom sides of the drum through the high pressure steam pipes to the high pressure cylinders. Steam from both high pressure cylinders exhausts through their respective receiver pipes and the boiler casting into the front or low pressure section of the superheater drum. It circulates over tubes between baffle plates and then passing through the low pressure steam pipe, enters the low pressure valves and cylinders, expands and exhausts into the stack.

Advantages.

The principal advantages of all types of this tubular drum superheater are as follows:

(1) LARGE HEATING SURFACE.—The effective area is from 1,500 to 2,000 sq. ft.

(2) MORE AVAILABLE HEATING SURFACE.—The heating surface is all available, as the gases circulate through the tubes and surround the section. Since the shell walls are as thin as practicable, they are as effective as the tubes in providing heating surface.

(3) LOW COST OF MAINTENANCE.—As the flues or fire tubes of the rear section are welded into the tube sheets and all steam pipe connections are provided with ball joints, the possibility of leaks is reduced to a minimum.

(4) LIGHTNESS.—The construction is as light throughout as the factor of safety will permit, thus giving the greatest possible area for heating surface for the weight of superheater.

(5) READY ACCESSIBILITY TO ALL PARTS.—In case of repairs being necessary all parts are easy to get at.

(6) EASILY REMOVED FROM SMOKE ARCH.—As the superheater is composed of two sections it can easily be removed from the smoke arch by simply removing nuts from the retaining bolts and studs. The superheaters of this type, however, need not be removed from the engine until the locomotive requires general overhauling.

(7) DEFECTIVE BOILER TUBES CAN BE REPAIRED WITHOUT REMOVING THE SUPERHEATER.—This may be accomplished by a man working in the space between the front flue sheet of the boiler and the back section of the superheater. Tubes can be cut out and passed out either through the fire door or through a large flue in the superheater provided for that purpose. A manhole in the bottom of the smoke arch allows a boilermaker to enter the space between the back section of the superheater and the front flue sheet.

(8) REACHES HIGH TEMPERATURES QUICKLY.—As all parts of superheater are constructed of light material, there are no massive headers or other sections slow to absorb heat. As a result, a high temperature is reached quickly when the engine is again working steam after having been shut off for some time; as, for instance, when standing on a siding.

(9) REDUCES SPARK THROWING.—The arrangement of opening through the superheater so controls the draft as to pull evenly over all parts of the fire, thus doing away with the necessity of a diaphragm, and all sparks and cinders are so completely broken up as to dispense with the netting.

The front end superheater, located as it is, in the path of hot gases that have passed out of the flues, utilizes heat energy retained in the gases that would otherwise be carried up the stack with the exhaust steam and wasted. There is no sacrifice of flue heating surface and no absorption of heat by the superheater during the passage of gases through the boiler flues. The smokebox superheater, therefore, utilizes waste heat only, and does not decrease boiler efficiency by absorbing heat which would generate saturated steam.

*Particulars of tests of these two engines are given elsewhere in this issue.

Notes on Granolithic Finish for Factory Floors.

An inquiry concerning the experience of users with granolithic (hard-finish concrete) floor-surfaces, as compared with wooden floor-surfaces, was recently made by the Aberthaw Construction Co., of Boston, Mass. The general results of this inquiry have been communicated to us with the company's specifications for granolithic floor finish. The following is an abstract; it will be understood that all the statements and opinions are those of the Aberthaw company.

Statements of Factory and Shop Owners.

The two questions below were put to about 200 owners of shops and factories.

1. From your experience, do you believe that a granolithic or other masonry surface is actually bad for the operatives, and why?
2. What objections do you know to granolithic finish that would make it advisable to incur greater expense for some other surface?

Over half (118) of the parties addressed made reply, but because of the form of many of the replies a tabular summary could not be made.

Of 18 paper-mills reporting experience with granolithic floors, 8 recommended such floors on all counts, while 10 made various unfavorable comments. It was generally conceded that the floors are durable and waterproof, but they are claimed to be a trifle hard on the men.

Two textile mills took opposing sides. One stated that the granolithic floor of its dye-house is not injurious to the operatives, while the other believed it better that the men should have a wood floor to stand on. This latter mill said that they had found no cement pavement which would stand the trucking of cloth without destructive wear.

Of miscellaneous establishments, a dozen or so replied, with opinions both for and against a bad effect on operatives. Some complained that their granolithic floors are quite dusty.

Two-thirds of the replies were from machine shops, and of these three-fourths reported personal experience with granolithic floors. Of the latter, one-third favored granolithic floor surfaces on every count, while two-thirds had criticisms to make, either of deficient wearing quality or of bad effect on the men. The favorable replies seem to indicate that well-made floors will be free from cause for dissatisfaction. One of these replies, for example, says:

> We have never had any complaint from any of our employees on granolithic surface in our plant. When we started to put concrete floors in our machine shop some doubts were expressed by our master mechanic and steam fitter that dropping castings, pieces of pipe, etc., on the floor would soon have it in bad shape. It has been in use at least three years and is in perfect condition; in fact as good as the day we finished work on it. We do not know of any objections to granolithic surface that would make it advisable to incur a greater expense for some other surface.

The objections made to granolithic floors on the score of their being bad to stand on are to be explained largely by the "cold" feel of the concrete, like that of stone, and not particularly by its greater hardness as compared with wood. In the shop of the Morse Chain Co. at Ithaca, N. Y., the heating of the building is accomplished by radiation from the concrete floor, steam-pipes being imbedded in the concrete, and there is complaint by the men against "hardness" of the floor. As this is taken as further proof that the cold feel of concrete floors is the real source of the complaints, it is recommended that where, in shops having concrete floors, workmen have to stand continuously in one place, wooden gratings to stand on be supplied for the men.

The complaints of poor wearing quality of concrete floors were nearly all from cases where heavily-loaded shop trucks were operated on the floors. Where granolithic or concrete floors are marked off in squares, the attack of truck wheels on the edges and corners of the squares is bound to prove destructive. The Aberthaw company advises against such marking, however, because its only purpose, to prevent expansion cracks, is ineffective when the surfacing concrete is thoroughly bonded to the concrete below, as should always be the case (otherwise the surfacing will peel). Where the trucking is so heavy that even a smooth (unmarked) granolithic surface would be cut, the company recommends convexing the truck-wheels slightly, to prevent the direct bearing of the edges of the wheels. Where even this expedient will not answer, because of very heavy loading of the trucks, iron or steel plates or bar gratings should be imbedded in the surface of the concrete.

The dust question, according to the experience of the Aberthaw company, is never encountered when the floor is made properly, with best workmanship and of best materials. Where the wear caused by trucking, etc., produces actual disintegration of the surface, dust must be expected, but such disintegration should be prevented as noted above. Painting concrete floors is not favored by the company, at least when considered as dust-preventive, because the protection will soon be destroyed by wear. When it must be used, a coat of boiled linseed oil thinned with gasoline or naphtha is recommended.

Specifications for Granolithic Finish.

A granolithic floor-surface needs to be troweled hard to make it at all durable. It can be put on at the same time as the under concrete, or can be put on at any time during the construction of the building, but if the under concrete is wet a better surface will be obtained. To give good service the aggregate must be a hard, tough stone; many stones that are hard are so brittle that they crack under a slight blow, and will come out from the cement, leaving a pocket which becomes a center for further breaking down.

The best result is obtained with a finishing mixture that is rather dry, wet enough to make a good bond with the green floor-slab underneath, but dry enough so that prolonged troweling is required to secure a film of water on the surface. The trowel, in its contact with the aggregate, should arrange the pieces of stone so that they lie with flat faces uppermost. When the granolithic finish is completed the aggregate should show on the surface in innumerable points or flat surfaces with the solid cement between.

These principles are the foundation of the following specifications of the Aberthaw Construction Co.:

> These specifications contemplate work in localities where tough stone is available; local conditions will govern the selection of other materials.

If the surface is to be laid upon an unset concrete base, the specifications should require that it be laid as soon after the base is in as may be, and if possible before the under concrete has set, so that the base and the finish shall bond together; otherwise the specification will apply.

MIXTURE of the top finish should be in the proportion of 1 part Portland cement; 1 part stone from ½-in. to the smallest size, excluding dust; and 1 part sharp sand (no grains passing a 50 screen, the majority of sizes which will pass between a 20 and a 30 screen). This shall be mixed to a stiff paste, just wet enough so that in troweling the water will barely work to the surface.

BASE.—If old concrete, the surface shall be roughened either by sand blast, acid treatment, or other equally satisfactory method of cleaning the stones so that the mortar shall adhere to them. The under concrete shall be thoroughly wet, and shall be kept wet long enough to absorb all the water it will take up readily, thus insuring a base so wet that it will not draw water from the finish when the latter is applied. Before scrubbing the base with grout, the excess of water shall be removed so that the finish shall not become too wet.

FINISH.—The surface of the base shall first be scrubbed with a thin grout of pure cement rubbed in with a broom. On top of this, before the thin coat has set, a thin coat of finish, mixed as above specified, shall be troweled hard, using as much pressure as possible, and rubbing the finish hard down on to the roughened base so that it shall take firm bond. After this, the finish shall be applied of the desired thickness, screeded, and floated to a true surface. Between the time of the initial and final set, it shall be finished by skilled workmen with steel trowels and worked to final surface. Under no condition shall dryer be used, nor shall water be added to make the material work easily.

It is to be understood that with the mixture specified, the surface will show slightly pebbled because of the small pieces of stone. It will not be possible to get so slick a job as can be obtained by using sand alone, and this is not expected.

If the finishing is done in hot weather, the finish shall be protected from sun and wind in order to prevent too rapid setting.

Arch Coefficients. Transformation of Dimensions in Symmetrical Rib Arches; with Tables of Coefficients for Twenty Arches of Different Proportions.

By MALVERD A. HOWE.*

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In a previous article on the calculation of stresses in symmetrical fixed-end rib arches (Engineering News, May 12, 1910, p. 553), it was stated that the computed values of horizontal thrust H, end moments M_1 and M_2, etc., could be utilized even though it should be necessary to change the thickness of ring, the span length, or the rise. The proof of this statement, and a demonstration of how such modifications of dimension may be made with little extra calculation is given in the following.

Assume that for a certain arch ring, of span l and rise f and of shape symmetrical about the center line of span, the values of H, M_1, M_2, V_1 and V_2 have been computed for unit loads, as explained in the article referred to above. The loads are for convenience applied at the numbered points, Fig. 1.

Horizontal Thrust.

The horizontal thrust is given by the following formula:

$$H = \frac{\Sigma\, m_x \triangle \left(y - \dfrac{\Sigma\, y \triangle}{\Sigma \triangle} \right)}{\Sigma\, y \triangle \left(y - \dfrac{\Sigma\, y \triangle}{\Sigma \triangle} \right)} = \frac{\Sigma\, m_x \triangle\, (y - K)}{\Sigma\, y \triangle\, (y - K)} \qquad (1)$$

Where Σ signifies a sum taken over the entire span, and

m_x = the moment produced by the loading considering the arch-rib as a simple beam resting on two supports.

$\triangle_1$, $\triangle_2$, etc., $= \dfrac{\delta s_1}{I_1}, \dfrac{\delta s_2}{I_2}$, etc.

δs_1, δs_2, etc., = portions of arch axis as shown in Fig. 1.

I_1, I_2, etc., = the moments of inertia of the radial section of the arch-ring at points 1, 2, etc.

x, y = coordinates of any point on the arch,

and $K = \dfrac{\Sigma y \triangle}{\Sigma \triangle}$ = constant for a given arch.

For the present purpose let the span always be divided into twenty equal divisions, i. e., $\delta x = l \div 20$.

If both numerator and denominator of a fraction are divided by the same quantity, the value of the fraction remains unchanged. In eq. (1), let both terms of K be divided by $\triangle_{10}$, the value of $\triangle$ in the section adjacent to the crown; and let both terms of the entire expression for H be divided by $f\triangle_{10}$, where f is the rise of the arch; then:

$$H = \frac{\Sigma\, m_x \dfrac{\triangle}{\triangle_{10}} \left(\dfrac{y}{f} - \dfrac{\Sigma \dfrac{y}{f} \dfrac{\triangle}{\triangle_{10}}}{\Sigma \dfrac{\triangle}{\triangle_{10}}} \right)}{f \Sigma \dfrac{y}{f} \dfrac{\triangle}{\triangle_{10}} \left(\dfrac{y}{f} - \dfrac{\Sigma \dfrac{y}{f} \dfrac{\triangle}{\triangle_{10}}}{\Sigma \dfrac{\triangle}{\triangle_{10}}} \right)} - \frac{1}{f} \frac{\Sigma\, m_x \triangle' \left(y' - \dfrac{\Sigma\, y' \triangle'}{\Sigma \triangle'} \right)}{\Sigma\, y' \triangle' \left(y' - \dfrac{\Sigma\, y' \triangle'}{\Sigma \triangle'} \right)}$$

$$= \frac{1}{f} \frac{\Sigma\, m_x \triangle' \left(y' - \dfrac{K}{f} \right)}{\Sigma\, y' \triangle' \left(y' - \dfrac{K}{f} \right)} = \frac{1}{f} \frac{\Sigma\, m_x \triangle'\, (y' - K')}{\Sigma\, y' \triangle'\, (y' - K')} \qquad (2)$$

Suppose the arch to be loaded with a single load W distant $a = k \dfrac{\delta x}{2}$ from the left support; then

$$m_x = W \left[z \frac{40 - k}{40} - \begin{pmatrix} z - k \\ \text{when } z \\ \text{exceeds } k \end{pmatrix} \right] \frac{\delta x}{2} = m'_x \frac{\delta x}{2}$$

in which m'_x is independent of the span and rise of the arch axis. Substituting this value in eq. (2) we get

$$H = \frac{\Sigma\, m_x' \triangle' (y' - K')}{\Sigma\, y' \triangle' (y' - K')} \frac{1}{f} \frac{\delta x}{2} = H' \frac{\delta x}{2f} \qquad (3)$$

The coefficient H' is the horizontal thrust for an arch ring having a *span of* 40, a *rise of* 1, and values of y' and $\triangle'$ *which vary in the same manner as the values of* y *and* $\triangle$ for the original or base arch ring. Knowing the value of H, the value of the coefficient H' becomes

$$H' = \frac{2f}{\delta x} H = \frac{40 f}{l} H \text{ [for twenty divisions]} \qquad (4)$$

By the use of H' the value of the thrust H'' for an arch ring with a span of l'' and a rise of f'' is readily found, for

$$H'' = \frac{\delta x''}{2f''} H' = \frac{l''}{40 f''} H' \qquad (5)$$

The dimensions of the new arch ring and the shape of its axis are readily found. The values of y' were obtained by dividing each value of y of the original or base arch axis by its rise f; and the values of $\triangle'$ are the quotients of each original value of $\triangle$ divided by $\triangle_{10}$, the original value of $\triangle$ at point No. 10. Therefore in the new arch, for a span of l'' and a rise of f'',

$$y_1'' = f'' y_1' \quad y_2'' = f'' y_2' \quad y_3'' = f'' y_3' \text{ etc.} \qquad (6)$$

$$\triangle_1'' = \triangle_{10}'' \triangle_1' \quad \triangle_2'' = \triangle_{10}'' \triangle_2' \quad \triangle_3'' = \triangle_{10}'' \triangle_3' \text{ etc.} \qquad (7)$$

Knowing the span l'' and the ordinates y'' the arch axis may be drawn to scale and the values of $\delta s_1''$, $\delta s_2''$, $\delta s_3''$ to $\delta s_{10}''$ determined. The next step is to assume the depth of the ring and the reinforcement at point No. 10 and compute the corresponding moment of inertia I_{10}, then $\triangle_{10}'' = \delta s_{10}'' \div I_{10}''$ and the values of $\triangle''$ at other points can be found by simple multiplication. Since $\triangle'' = \delta s'' \div I''$; $I_1'' = \delta s_1'' \div \triangle_1''$; $I_2'' = \delta s_2'' \div \triangle_2''$; $I_3'' = \delta s_3'' \div \triangle_3''$, etc., thus determining the moments of inertia at each point. From the values of the moments of inertia the corresponding depth of ring is found.

The curves forming the upper and lower limits of the ring will not be regular curves as a rule, but usually they can be very closely approximated by circular arcs.

If the axis of the original arch axis was an arc of a circle the new axis will be a portion of an ellipse.

Moments at the Supports.

The formula used in routine calculations when the span is divided into twenty equal parts is, for unit loads

$$\left.\begin{matrix} M_1 \\ M_2 \end{matrix}\right\} = H \frac{\Sigma y \triangle}{\Sigma \triangle} - \left\{ \left[\sum_{z=0}^{z=k} z \triangle + k \sum_{z>k}^{z=19} \triangle \right] \frac{\delta x}{2 \Sigma \triangle} \pm \left[(20 - k) \sum_{z=0}^{z=k} 20 (z - 20) \triangle - k \sum_{z>k}^{z=19} (z - 20)^2 \triangle \right] \frac{\delta x}{2 (400 \Sigma \triangle - \Sigma z^2 \triangle)} \right\} \qquad (8)$$

If $H \dfrac{\Sigma y \triangle}{\Sigma \triangle}$ is replaced by

$$H' \frac{\delta x}{2f} \cdot \frac{\Sigma y' \triangle'}{\Sigma \triangle'} f = H' \frac{\Sigma y' \triangle'}{\Sigma \triangle'} \frac{\delta x}{2},$$

and the remainder of the expression divided (numerators and denominators) by $\triangle_{10}$, the value of the expression will not be changed, but it will become apparent that the whole expression is independent of span, rise, and thickness of ring. It may be written

$$\left.\begin{matrix} M_1 \\ M_2 \end{matrix}\right\} = \left\{\begin{matrix} M_1' \\ M_2' \end{matrix}\right\} \frac{\delta x}{2} \qquad (9)$$

where M_1' and M_2' are the moments at the supports for a span of 40 and a rise of unity and a ring having values of y' and $\triangle'$ as explained above. The values of M_1' and M_2' are quickly found by dividing the values of M_1 and M_2 found for the original or base arch ring by $\dfrac{\delta x}{2} = \dfrac{l}{40}$.

For an arch ring having a span of l'' and a rise of f''

$$M_1'' = M_1' \frac{\delta x''}{2} = M_1' \frac{l''}{40}$$

and

$$M_2'' = M_2' \frac{\delta x''}{2} = M_2' \frac{l''}{40}$$

Note that the change in rise has no influence upon the values of the moments when the coefficients are employed. In general then

$$M_2 : M_2'' :: l : l'' \text{ and } M_1 : M_1'' :: l : l'' \ldots (10)$$

Vertical Reactions.

The vertical reaction at the left support is

$$V_1 = \frac{M_2 - M_1}{l} + R_1 \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

where R_1 is the reaction assuming the arch to be a beam simply supported at the ends. This latter

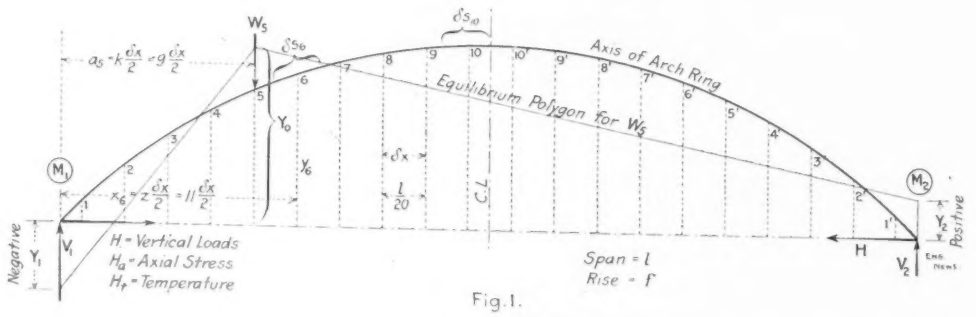


Fig. 1.

*Professor of Civil Engineering, Rose Polytechnic Institute, Terre Haute, Ind.

is independent of the length of span; hence for a span l''

$$V_1'' = \frac{M_2'' - M_1''}{l''} + R_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

but

$$M_2'' = \frac{M_2 l''}{l} \text{ and } M_1'' = \frac{M_1 l''}{l}$$

therefore

$$V_1'' = \frac{M_2 - M_1}{l} + R_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

or, the *value of the vertical reaction at the left support remains unchanged for changes in length of span.* The rise of the arch axis does not appear and hence has no effect.

Ordinates Locating the Equilibrium Polygon.

The ordinates Y_1, Y_0, and Y_2, Fig. 1, which locate the equilibrium polygon, change with the rise only:

$$Y_1 = \frac{M_1}{H_1} = \frac{M'_1 \dfrac{\delta x}{2}}{H' \dfrac{\delta x}{2 f}} = \frac{M'_1}{H'} f \qquad (14)$$

$$Y_1'' = \frac{M_1''}{H_1''} = \frac{M_1' \dfrac{\delta x''}{2}}{H' \dfrac{\delta x''}{2 f'}} = \frac{M_1'}{H'} f' \qquad (15)$$

$$\therefore Y_1 : Y_1'' :: f : f' \text{ or } Y_1'' = Y_1 \frac{f'}{f} \qquad (16)$$

In like manner

$$Y_0'' = Y_0 \frac{f'}{f} \text{ and } Y_2'' = Y_2 \frac{f'}{f} \qquad (17)$$

Intermediate Moments.

The moment at any intermediate point of the arch, for a single load W, can be found from the general formula:

$$M_x = M_1 + V_1 x - H y - \begin{bmatrix} \text{when } x > a \\ W(x-a) \end{bmatrix} \qquad (18)$$

or

$$M_x = \left\{ M_1' \frac{\delta x}{2} + V_1 z \frac{\delta x}{2} - H' y' \frac{\delta x}{2} - \left[\begin{matrix} \text{when } z > k \\ W(z-k) \end{matrix} \frac{\delta x}{2} \right] \right\} \qquad (19)$$

and for a unit load

$$M_x = \left\{ M_1' + V_1 z - H' y' - \left[\begin{matrix} \text{when } x > k \\ (z-k) \end{matrix} \right] \right\} \frac{\delta x}{2} \qquad (20)$$

Then for any other span $l'' = 20\delta x''$, the corresponding moment is

$$M_x'' = \left\{ M_1' + V_1 z - H' y' - \left[\begin{matrix} \text{when } z > k \\ (z-k) \end{matrix} \right] \right\} \frac{\delta x''}{2} \qquad (21)$$

Therefore

$$M_x : M_x'' :: \frac{\delta x}{2} : \frac{\delta x''}{2} :: l : l''$$

and

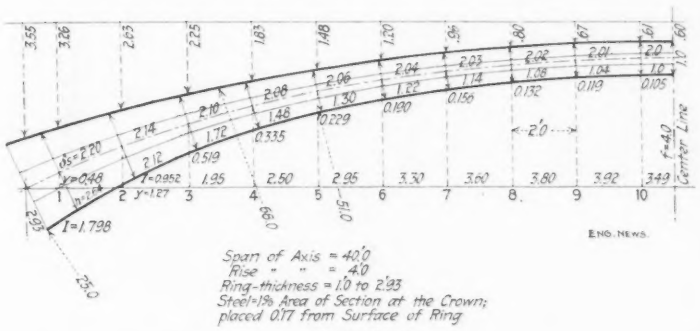
$$M_x'' = M_x \frac{l''}{l} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (22)$$

Temperature.

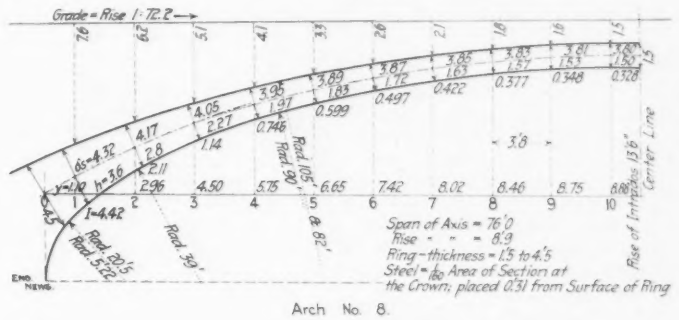
The horizontal thrust produced by a change in temperature is

$$H_t = \frac{e\, t^\circ E\, l}{\Sigma\, y\, \triangle \left(y - \dfrac{\Sigma\, y\, \triangle}{\Sigma\, \triangle} \right)} \qquad (23)$$

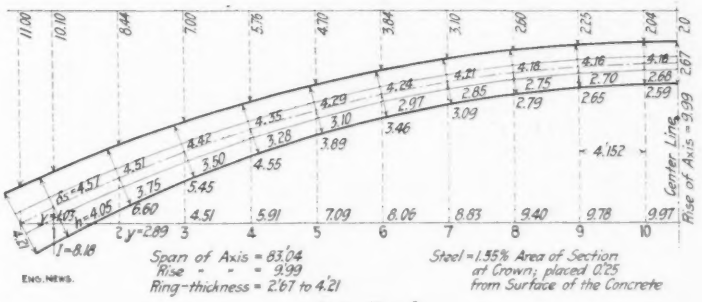
where e = coefficient of expansion.
t° = number of degrees change.
E = Young's modulus.


Span of Axis = 40'0
Rise " " = 4.0
Ring-thickness = 1.0 to 2'93
Steel=1% Area of Section at the Crown; placed 0.17 from Surface of Ring
ENG. NEWS.

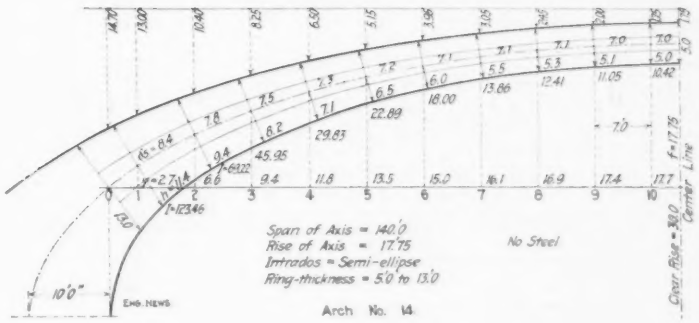
Arch No. 3.


Grade = Rise 1 : 72.2
Span of Axis = 76'0
Rise " " = 8.9
Ring-thickness = 1.5 to 4.5
Steel = 1/60 Area of Section at the Crown; placed 0.31 from Surface of Ring
ENG. NEWS.

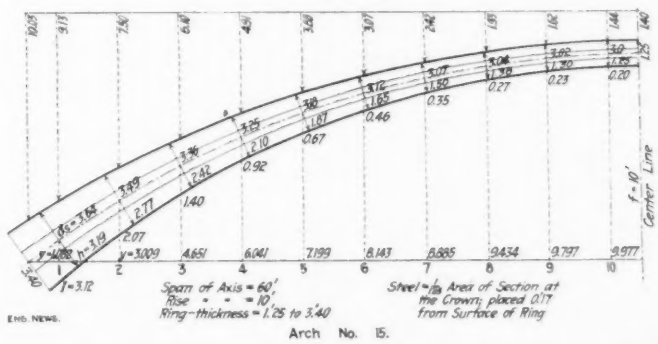
Arch No. 8.


Span of Axis = 83.04
Rise " " = 9.99
Ring-thickness = 2.67 to 4.21
Steel = 1.55% Area of Section at Crown; placed 0.25 from Surface of the Concrete
ENG. NEWS.

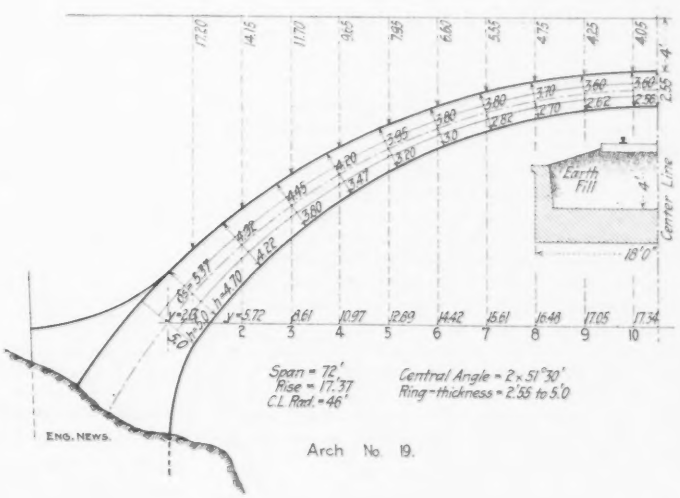
Arch No. 9.



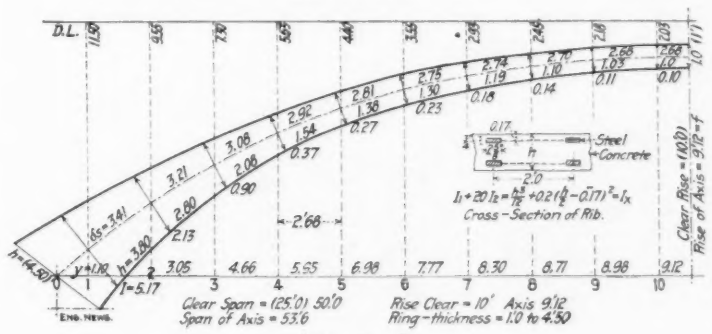
Arch No. 14.


Span of Axis = 60'
Rise " " = 10'
Ring-thickness = 1.25 to 3.40
Steel = 1/100 Area of Section at the Crown; placed 0.17 from Surface of Ring
ENG. NEWS.

Arch No. 15.



Arch No. 19.



Arch No. 17.

DIAGRAMS OF TYPICAL ARCHES INCLUDED IN THE TABLES OF COEFFICIENTS.

If the terms of the denominator of equation (23) be divided by $f^2\triangle_{10}$, introduced as a factor, the whole expression is not changed in value. It becomes

$$H_t = \frac{e\,t^o\,E\,I}{\Sigma\, y'\,\triangle'\left(y' - \frac{\Sigma\, y'\triangle'}{\Sigma\,\triangle'}\right) f^2\,\triangle_{10}} = \frac{e\,t^o\,E\,I}{D'\,\triangle_{10} f^2} \qquad (24)$$

For a change of span to l'' and change of rise to f'',

$$H_t'' = \frac{e\,t^o\,E\,I''}{D'\,\triangle''_{10}\,f''^2} \qquad (25)$$

Then

$$H_t : H_t'' :: \frac{I}{D'\,\triangle_{10} f^2} : \frac{I''}{D'\triangle''_{10}\,f''^2} \qquad (26)$$

$$\text{or } H_t'' = H_t \frac{\triangle_{10}}{\triangle''_{10}} \cdot \frac{I''}{I}\left(\frac{f}{f''}\right)^2 \qquad (27)$$

The value of H_t'' can be found either from equation (25), using the coefficient D', already found in computing H, or from the proportion given in equation (27).

The moment at either support is, for the original arch:

$$M_{1t} = M_{2t} = H_t \frac{\Sigma\, y\,\triangle}{\Sigma\,\triangle} = H_t \frac{\Sigma\, y'\,\triangle'}{\Sigma\,\triangle'} f = H_t\, K'\, f$$

and for the arch with span l'' and rise f'':

$$M_{1t}'' = M_{2t}'' = H_t''\, K'\, f'' \qquad (28)$$

or

$$M_{1t} : M_{1t}'' :: H_t\, K'\, f : H_t''\, K'\, f''$$

and

$$M_{1t}'' = \frac{H_t''}{H_t}\,\frac{f''}{f}\, M_{1t} \qquad (29)$$

The value of M_{1t}'' can be found from (28) by using the coefficient K', already found, or from eq. (29).

The Axial or Direct Stress.

The effect of the axial stress may be considered as the effect of a drop in temperature, and consequently it is necessary to consider its effect upon the horizontal thrust alone.

$$H_a = -\,H\left\{\frac{1 - \dfrac{D}{D + \left(\dfrac{\delta x}{\Sigma\, F\,\delta s}\right)^2 \dfrac{1}{\Sigma\, F\,\delta s}}}{}\right\} \qquad (30)$$

$$H_a = -\,H\,\frac{(\delta x)^2\,\dfrac{1}{\Sigma\, F\,\delta s}}{D'\,\triangle_{10} f^2 + (\delta x)^2\,\dfrac{1}{\Sigma\, F\,\delta s}} \qquad (31)$$

For a ring with a span l'' and a rise f''.

$$H_a'' = -\,H''\,\frac{(\delta x'')^2\,\dfrac{1}{\Sigma\, F''\,\delta s''}}{D'\,\triangle''_{10} f''^2 + (\delta x'')^2\,\dfrac{1}{\Sigma\, F''\,\delta s''}} \qquad (32)$$

In the above equations F is the effective area of the radial section of the ring at the point being considered.

Summary.

Given an arch ring of a certain shape and certain rate of variation of the ring-thickness function $\triangle$ ($= \delta s \div I$), it is possible to change the span l and the rise f of the axis of this ring to a span l'' and a rise f'', provided that the ordinates y'' and the function $\triangle''$ for the new ring vary according to the same laws as y and $\triangle$ of the original ring. Then the values of H'', M_1'', M_2'', etc., may be found directly from the values of H, M_1, M_2, etc., of the first arch ring, by the help of the following expressions, in which the square brackets denote derived coefficients which are independent of span and rise:

$$\text{Ordinates, } y'' = \frac{y}{f} f'' = [y']\, f'' \qquad (6)$$

$$\text{Ring—Thickness function, } \triangle'' = \frac{\triangle}{\triangle_{10}}\,\triangle''_{10} = [\triangle']\,\triangle''_{10} \qquad (7)$$

$$\text{Unit-load thrust, } H'' = \frac{\delta x''}{2 f''} \cdot \frac{2 f}{\delta x} H = \frac{\delta x''}{2 f''}\,[H'] \qquad (5)$$

$$\text{Temperature thrust, } H_t'' = \frac{\triangle_{10}}{\triangle''_{10}} \cdot \frac{I''}{I}\left(\frac{f}{f''}\right)^2 H_t \qquad (27)$$

$$\text{Temperature moment at left support } M''_{1t} = M''_{2t} = \frac{H_t''}{H_t}\,\frac{f''}{f}\,M_{1t} = H_t''\, f''\,[K'] \qquad (29)$$

$$\text{Unit-load moment at left } M_1'' = \frac{I''}{I} M_1 = \frac{\delta x''}{2}\,[M_1'] \qquad (9)$$

$$\text{At right support } M_2'' = \frac{I''}{I} M_2 = \frac{\delta x''}{2}\,[M_2'] \qquad (9)$$

$$\text{Reactions } V_1'' = [V_1] \text{ and } V_2'' = [V_2] \qquad (13)$$

$$\text{Ordinates of equilibrium polygon for single load } Y_1'' = Y_1 \frac{f''}{f} \qquad Y_o'' = Y_o \frac{f''}{f}$$

$$Y_2'' = Y_2 \frac{f''}{f} \qquad (14)-(17)$$

$$\text{Unit-load moment at any point } x \; M_x'' = \frac{I''}{I} M_x \qquad (22)$$

$$\text{Thrust due to axial stress } H_a'' = -H''\,\frac{(\delta x'')^2 \dfrac{1}{\Sigma F''\delta s''}}{[D']\triangle''_{10} f''^2 + (\delta x'')^2 \dfrac{1}{\Sigma F''\delta s''}} \qquad (32)$$

The formulas for the coefficients are:

$$[y'] = \frac{y}{f}$$

$$[\triangle'] = \frac{\triangle}{\triangle_{10}}$$

$$[K'] = \frac{\Sigma\, y'\,\triangle'}{\Sigma\,\triangle'} = \frac{1}{f}\,\frac{\Sigma\, y\,\triangle}{\Sigma\,\triangle} = \frac{K}{f}$$

$$[D'] = \Sigma\, y'\,\triangle'\,(y' - K') = \frac{D}{f^2\,\triangle_{10}}$$

$$[H'] = H\,\frac{40\,f}{I} = \frac{\Sigma\, m_x'\,\triangle'\,(y' - K')}{D'}$$

in which m_x' is the simple-beam moment of a single load of unity for a span of 40, or

$$m_x' = m_x \frac{40}{I}$$

$$\left.\begin{matrix}[M_1'] \\ [M_2']\end{matrix}\right\} = \left\{\begin{matrix} M_1 \dfrac{40}{I} \\ M_2 \dfrac{40}{I}\end{matrix}\right\}$$

$$= H'\,K' - \frac{1}{\Sigma\triangle'}\left(\sum_{z=0}^{z=k} z\,\triangle' + k \sum_{z>k}^{z=19}\triangle'\right)$$

$$\pm\frac{\left((20-k)\sum_{z=20}^{z=k} 20\,(z-20)\,\triangle' - k\sum_{z=k}^{z=19}(z-20)^2\,\triangle'\right)}{400\,\Sigma\,\triangle' - \Sigma\, z^2\,\triangle'}$$

$$[V_1] = R_1 + \frac{M_2 - M_1}{I}$$

$$[V_2] = R_2 - \frac{M_2 - M_1}{I}$$

Tables of Coefficients of Twenty Arches.

The appended tables contain the above coefficients for twenty different arch rings. The original or base arches had either segmental or false elliptic intrados. By the methods above given, these tables may be used for analyzing any similar arch. Of course the greatest utility of the coefficients is for comparatively small changes in span or rise or both.

TABLES OF ARCH COEFFICIENTS.

ARCH NO. 1.

Base: $l = 100$; $f = 8.333$; $f \div l = 0.0833$; $D' = 0.2498$; $K' = 0.878$; $\Sigma M_1' = -21.550 + 21.850$.

Point No.	y'	$\triangle'$	H'	M_1'	M_2'	V_1	V_2
1	0.0996	0.0579	0.000	−1.000	0.000	1.000	0.000
2	.2820	.0689	.401	−2.474	.218	.992	.008
3	.4392	.0856	1.163	−3.444	.614	.976	.024
4	.5820	.1108	2.260	−3.909	1.150	.951	.049
5	.7008	.1461	3.649	−3.876	1.779	.916	.084
6	.8004	.1990	5.269	−3.365	2.436	.870	.130
7	.8796	.2821	7.026	−2.411	3.030	.811	.189
8	.9348	.3905	8.779	−1.071	3.420	.737	.263
9	.9768	.5718	10.338	.466	3.542	.651	.348
10	.9972	1.0000	11.405	2.040	3.155	.552	.447
		2.9118	50.290	M_2'	M_1'	V_2	V_1

ARCH NO. 2.

Base: $l = 100$; $f = 10$; $f \div l = 0.10$; $D' = 0.2539$; $K' = 0.876$; $\Sigma M_1' = -23.776 + 25.528$.

Point No.	y'	$\triangle'$	H'	M_1'	M_2'	V_1	V_2
1	0.102	0.0518	0.000	−1.000	0.000	1.000	0.000
2	.287	.0769	.316	−2.612	0.193	.995	.005
3	.450	.1134	.990	−3.766	.591	.984	.016
4	.590	.1696	2.043	−4.394	1.186	.964	.036
5	.706	.2486	3.479	−4.430	1.942	.934	.066
6	.805	.3644	5.248	−3.846	2.784	.891	.109
7	.882	.5041	7.221	−2.674	3.576	.831	.169
8	.940	.6967	9.170	−1.054	4.129	.755	.245
9	.976	.8200	10.769	.766	4.210	.661	.339
10	.997	1.0000	11.720	2.471	3.680	.555	.445
		4.0455	50.956	M_2'	M_1'	V_2	V_1

ARCH NO. 3.

Base: $l = 40$; $f = 4$; $f \div l = 0.10$; $D' = 0.3288$; $K' = 0.880$; $\Sigma M_1' = -21.367 + 29.369$.

Point No.	y'	$\triangle'$	H'	M_1'	M_2'	V_1	V_2
1	0.1200	0.0641	0.000	−1.000	0.000	1.000	0.000
2	.3175	.1181	.288	−2.665	.185	.996	.004
3	.4875	.2126	.968	−3.848	.606	.986	.014
4	.6250	.3260	2.128	−4.380	1.286	.967	.033
5	.7375	.4724	3.752	−4.190	2.168	.934	.066
6	.8250	.5638	5.728	−3.284	3.126	.885	.115
7	.9000	.6830	7.820	−1.856	3.984	.821	.179
8	.9500	.8032	9.748	−0.144	4.538	.742	.258
9	.9800	.8866	11.236	1.591	4.621	.651	.349
10	.9975	1.0000	12.072	3.107	4.157	.551	.449
		5.1298	53.740	M_2'	M_1'	V_2	V_1

ARCH NO. 4.

Base: $l = 80$; $f = 8$; $f \div l = 0.10$; $D' = 0.3323$; $K' = 0.862$; $\Sigma M_1' = -22.868 + 24.088$.

Point No.	y'	$\triangle'$	H'	M_1'	M_2'	V_1	V_2
1	0.1013	0.0726	0.000	−1.000	0.000	1.000	0.000
2	.2850	.1076	.332	−2.592	.197	.995	.005
3	.4475	.1549	1.038	−3.698	.597	.982	.018
4	.5872	.2213	2.128	−4.261	1.186	.961	.039
5	.7062	.3167	3.586	−4.240	1.917	.929	.071
6	.8037	.4383	5.338	−3.628	2.703	.883	.117
7	.8812	.5888	7.242	−2.487	3.414	.823	.177
8	.9400	.7646	9.076	−0.962	3.876	.746	.254
9	.9788	.9230	10.548	0.711	3.900	.655	.345
10	.9975	1.0000	11.366	2.236	3.351	.553	.447
		4.5877	50.654	M_2'	M_1'	V_2	V_1

ARCH NO. 5.

Base: $l = 100$; $f = 10$; $f \div l = 0.10$; $D' = 0.5729$; $K' = 0.811$; $\Sigma M_1' = -19.730 + 20.638$.

Point No.	y'	$\triangle'$	H'	M_1'	M_2'	V_1	V_2
1	0.101	0.1660	0.000	−1.000	0.000	1.000	0.000
2	.285	.2264	.412	−2.487	.215	.993	.007
3	.446	.2935	1.239	−3.413	.623	.976	.024
4	.585	.3862	2.441	−3.773	1.185	.949	.051
5	.704	.4608	3.948	−3.579	1.824	.910	.090
6	.802	.5682	5.627	−2.920	2.446	.859	.141
7	.879	.6979	7.325	−1.901	2.944	.796	.204
8	.939	.8182	8.858	−0.658	3.203	.722	.278
9	.977	.8999	10.027	0.632	3.121	.637	.363
10	.997	1.0000	10.675	1.799	2.652	.547	.453
		5.5171	50.552	M_2'	M_1'	V_2	V_1

ARCH NO. 6.

Base: $l = 79$; $f = 8$; $f \div l = 0.1012$; $D' = 0.3827$; $K' = 0.858$; $\Sigma M_1' = -18.157 + 33.851$.

Point No.	y'	$\triangle'$	H'	M_1'	M_2'	V_1	V_2
1	0.1438	0.0893	0.000	−1.000	0.000	1.000	0.000
2	.3600	.1846	.333	−2.618	.222	.996	.004
3	.5350	.3233	1.147	−3.645	.737	.985	.015
4	.6638	.4258	2.505	−3.921	1.545	.962	.038
5	.7688	.5513	4.295	−3.492	2.532	.926	.074
6	.8563	.6852	6.340	−2.462	3.545	.875	.125
7	.9125	.7780	8.390	−1.019	4.386	.810	.190
8	.9563	.8757	10.215	0.622	4.910	.732	.268
9	.9850	.9638	11.590	2.231	4.988	.644	.356
10	.9975	1.0000	12.320	3.592	4.541	.549	.451
		5.8770	57.135	M_2'	M_1'	V_2	V_1

ARCH NO. 7.

Base: $l = 79$; $f = 8.84$; $f \div l = 0.1119$; $D' = 0.3415$; $K' = 0.864$; $\Sigma M_1' = -18.980 + 35.831$.

Point No.	y'	$\triangle'$	H'	M_1'	M_2'	V_1	V_2
1	0.1425	0.0766	0.000	−1.000	0.000	1.000	0.000
2	.3598	.1522	.322	−2.636	.219	.996	.004
3	.5317	.2782	1.097	−3.714	.714	.986	.014
4	.6674	.4103	2.412	−4.096	1.542	.966	.034
5	.7715	.5726	4.198	−3.725	2.569	.931	.069
6	.8507	.7117	6.298	−2.674	3.651	.883	.117
7	.9095	.8095	8.455	−1.135	4.586	.818	.182
8	.9547	.9325	10.397	0.637	5.191	.739	.261
9	.9842	.9667	11.844	2.368	5.292	.648	.352
19	.9952	1.0000	12.614	3.824	4.831	.550	.450
		5.9103	57.637	M_2'	M_1'	V_2	V_1

ARCH NO. 8.

Base: $l = 76$; $f = 8.9$; $f \div l = 0.1171$; $D' = 0.4023$; $K' = 0.848$; $\Sigma M'_1 = -19.656 + 30.437$.

Point No.	y'	Δ'	H'	M_1'	M_2'	V_1	V_2
1	0.1236	0.0846	0.000	−1.000	0.000	1.000	0.000
2	.3326	.1700	.304	−2.651	.195	.996	.004
3	.5056	.3072	1.045	−3.766	.651	.986	.014
4	.6461	.4573	2.305	−4.167	1.379	.964	.036
5	.7472	.5599	4.024	−3.816	2.290	.928	.072
6	.8337	.6721	6.024	−2.837	3.241	.877	.123
7	.9011	.7868	8.066	1.419	4.051	.812	.188
8	.9506	.8766	9.902	0.222	4.559	.734	.266
9	.9832	.9448	11.284	1.838	4.621	.645	.355
10	.9978	1.0000	12.034	3.215	4.175	.549	.451
		5.8593	54.988	M'_2	M'_1	V_2	V_1

ARCH NO. 9.

Base: $l = 83.04$; $f = 9.99$; $f \div l = 0.1203$; $D' = 0.9263$; $K' = 0.767$; $\Sigma M'_1 = -17.398 + 17.981$.

Point No.	y'	Δ'	H'	M_1'	M_2'	V_1	V_2
1	0.1031	0.3478	0.000	−1.000	0.000	1.000	0.000
2	.2893	.4223	.500	−2.366	.231	.992	.008
3	.4515	.5031	1.434	−3.133	.645	.976	.024
4	.5916	.5839	2.704	−3.344	1.172	.949	.051
5	.7097	.6833	4.205	−3.082	1.728	.910	.090
6	.8068	.7640	5.780	−2.438	2.224	.859	.141
7	.8838	.8447	7.295	−1.534	2.577	.796	.204
8	.9409	.9317	8.594	−0.501	2.712	.721	.279
9	.9790	.9752	9.542	0.529	2.575	.637	.363
10	.9980	1.0000	10,042	1.444	2.144	.546	.454
		7.0550	50,096	M'_2	M'_1	V_2	V_1

ARCH NO. 10.

Base: $l = 60$; $f = 7.5$; $f \div l = 0.1250$; $D' = 0.2761$; $K' = .873$; $\Sigma M'_1 = -23.410 + 25.503$.

Point No.	y'	Δ'	H'	M_1'	M_2'	V_1	V_2
1	0.1027	0.0572	0.000	−1.000	0.000	1.000	0.000
2	.2894	.0854	.320	−2.612	.195	.995	.005
3	.4533	.1280	1.000	−3.759	.597	.984	.016
4	.5920	.1892	2.069	−4.364	1.197	.964	.036
5	.7107	.2780	3.523	−4.371	1.957	.933	.067
6	.8066	.3895	5.303	−3.756	2.796	.889	.111
7	.8840	.5343	7.269	−2.575	3.577	.829	.171
8	.9414	.7408	9.192	−0.973	4.113	.752	.248
9	.9786	.8496	10.746	0.812	4.171	.659	.341
10	.9973	1.0000	11.649	2.454	3.634	.555	.445
		4.2520	51.071	M'_2	M'_1	V_2	V_1

ARCH NO. 11.

Base: $l = 100$; $f = 12.5$; $f \div l = 0.1250$; $D' = 0.5698$; $K' = 0.818$; $\Sigma M'_1 = -19.612 + 21.730$.

Point No.	y'	Δ'	H'	M_1'	M_2'	V_1	V_2
1	0.1048	0.1685	0.000	−1.000	0.000	1.000	0.000
2	.2928	.2280	.417	−2.485	.224	.993	.007
3	.4552	.2938	1.254	−3.408	.654	.977	.023
4	.5944	.3865	2.465	−3.772	1.239	.950	.050
5	.7120	.5055	3.979	−3.590	1.907	.912	.088
6	.8072	.6026	5.681	−2.911	2.562	.862	.138
7	.8864	.7422	7.405	−1.860	3.092	.799	.201
8	.9424	.8870	8.952	−0.586	3.366	.724	.276
9	.9784	.9398	10.112	0.728	3.273	.639	.361
10	.9976	1.0000	10.742	1.963	2.782	.547	.453
		5.7513	51.007	M'_2	M'_1	V_2	V_1

ARCH NO. 12.

Base: $l = 76$; $f = 9.68$; $f \div l = 0.1273$; $D' = 0.3484$; $K' = 0.861$; $\Sigma M'_1 = -19.964 + 31.127$.

Point No.	y'	Δ'	H'	M_1'	M_2'	V_1	V_2
1	0.1291	0.0742	0.000	−1.000	0.000	1.000	0.000
2	.3358	.1407	.311	−2.640	.203	.996	.004
3	.5062	.2433	1.050	−3.753	.666	.985	.015
4	.6457	.3796	2.277	−4.196	1.391	.964	.036
5	.7521	.4728	3.979	−3.887	2.319	.930	.070
6	.8368	.5858	5.976	−2.947	3.298	.881	.119
7	.8998	.7446	8.051	−1.541	4.155	.817	.183
8	.9504	.8602	9.966	−0.158	4.723	.739	.261
9	.9835	.9612	11.434	1.867	4.822	.649	.351
10	.9990	1.0000	12.223	3.330	4.353	.551	.449
		5.4624	55.267	M'_2	M'_1	V_2	V_1

ARCH NO. 13.

Base: $l = 76$; $f = 9.68$; $f \div l = 0.1273$; $D' = 1.3506$; $K' = .704$; $\Sigma M'_1 = -9.226 + 29.676$.

Point No.	y'	Δ'	H'	M_1'	M_2'	V_1	V_2
1	0.1291	1.0000	0.000	−1.000	0.000	1.000	0.000
2	.3358	1.000	.857	−2.008	.420	.986	.014
3	.5062	1.000	2.265	−2.279	1.067	.959	.041
4	.6457	1.000	3.966	−1.992	1.792	.910	.090
5	.7521	1.000	5.755	−1.397	2.491	.872	.128
6	.8368	1.000	7.472	−0.550	3.070	.715	.185
7	.8998	1.000	8.990	0.379	3.479	.753	.247
8	.9504	1.000	10.218	1.304	3.672	.684	.316
9	.9835	1.000	11.073	2.155	3.633	.612	.388
10	.9990	1.000	11.514	2.855	3.359	.537	.463
		10.000	62.110	M'_2	M'_1	V_2	V_1

ARCH NO. 14.

Base: $l = 140$; $f = 18$; $f \div l = 0.1285$; $D' = 0.3356$; $K' = 0.849$; $\Sigma M'_1 = -17.350 + 35.663$.

Point No.	y'	Δ'	H'	M_1'	M_2'	V_1	V_2
1	0.1500	0.1012	0.000	−1.000	0.000	1.000	0.000
2	.3667	.1682	.421	−2.520	.273	.995	.005
3	.5222	.2426	1.326	−3.448	.834	.982	.018
4	.6556	.3646	2.703	−3.735	1.645	.960	.040
5	.7500	.4688	4.500	−3.346	2.626	.924	.076
6	.8333	.5863	6.572	−2.361	3.651	.875	.125
7	.8944	.7620	8.700	−0.940	4.546	.812	.188
8	.9389	.8512	10.618	0.729	5.118	.735	.265
9	.9667	.9420	12.083	2.393	5.230	.646	.354
10	.9833	1.0000	12.884	3.818	4.800	.550	.450
		5.4869	59.807	M'_2	M'_1	V_2	V_1

ARCH NO. 15.

Base: $l = 60$; $f = 10$; $f \div l = 0.1667$; $D' = 0.3279$; $K' = 0.863$ $\Sigma M'_1 = -21.676 + 25.658$.

Point No.	y'	Δ'	H'	M_1'	M_2'	V_1	V_2
1	0.1082	0.0780	0.000	−1.000	0.000	1.000	0.000
2	.3009	.1127	.359	−2.561	.215	.994	.006
3	.4651	.1600	1.103	−3.624	.647	.982	.018
4	.6041	.2353	2.237	−4.138	1.268	.960	.040
5	.7199	.3167	3.741	−4.052	2.030	.927	.073
6	.8143	.4520	5.533	−3.387	2.852	.881	.119
7	.8885	.5866	7.444	−2.217	3.572	.820	.180
8	.9434	.7507	9.263	−0.697	4.035	.743	.257
9	.9797	.8754	10.713	0.963	4.063	.652	.348
10	.9977	1.0000	11.207	2.465	3.548	.552	.448
		4.5674	51.600	M'_2	M'_1	V_2	V_1

ARCH NO. 16.

Base: $l = 100$; $f = 16.67$; $f \div l = 0.1667$; $D' = 0.5890$; $K' = 0.817$; $\Sigma M'_1 = -18.819 + 22.333$.

Point No.	y'	Δ'	H'	M_1'	M_2'	V_1	V_2
1	0.1086	0.1840	0.000	−1.000	0.000	1.000	0.000
2	.3012	.2395	.443	−2.455	.241	.992	.008
3	.4656	.3180	1.305	−3.347	.687	.976	.024
4	.6048	.4087	2.547	−3.667	1.289	.949	.051
5	.7224	.5115	4.085	−3.443	1.970	.910	.090
6	.8164	.6266	5.787	−2.752	2.625	.859	.141
7	.8892	.7564	7.491	−1.706	3.142	.796	.204
8	.9444	.8728	9.010	−0.450	3.496	.721	.279
9	.9804	.9580	10.152	0.838	3.320	.637	.363
10	.9972	1.0000	10.763	1.979	2.836	.546	.454
		5.8755	51.583	M'_2	M'_1	V_2	V_1

ARCH NO. 17.

Base: $l = 53.6$; $f = 9.12$; $f \div l = 0.1701$; $D' = 0.19404$; $K' = 0.893$; $\Sigma M'_1 = -22.735 + 37.903$.

Point No.	y'	Δ'	H'	M_1'	M_2'	V_1	V_2
1	0.1206	0.0246	0.000	−1.000	0.000	1.000	0.000
2	.3345	.0563	.196	−2.782	.142	.998	.002
3	.5110	.1276	.718	−4.179	.509	.992	.008
4	.6525	.2944	1.743	−4.939	1.196	.978	.022
5	.7654	.3885	3.504	−4.661	2.290	.948	.052
6	.8520	.4403	5.782	−3.480	3.578	.901	.099
7	.9102	.5679	8.254	−1.694	4.806	.837	.163
8	.9551	.7194	10.636	0.465	5.751	.757	.243
9	.9847	.9000	12.568	2.678	6.153	.662	.338
10	.9999	1.0000	13.656	4.561	5.774	.555	.445
		4.534	57.057	M'_2	M'_1	V_2	V_1

ARCH NO. 18.

Base: $l = 40$; $f = 8$; $f \div l = 0.2000$; $D' = 0.6252$; $K' = 0.812$; $\Sigma M'_1 = -17.857 + 22.787$.

Point No.	y'	Δ'	H'	M_1'	M_2'	V_1	V_2
1	0.1138	0.2084	0.000	−1.000	0.000	1.000	0.000
2	.3113	.2735	.464	−2.429	.251	.992	.008
3	.4775	.3527	1.368	−3.269	.717	.975	.025
4	.6150	.4404	2.648	−3.529	1.337	.947	.053
5	.7288	.5423	4.208	−3.265	2.019	.907	.043
6	.8212	.6588	5.904	−2.559	2.663	.856	.144
7	.8925	.7722	7.584	−1.517	3.165	.792	.208
8	.9462	.8736	9.072	−.289	3.417	.718	.282
9	.9800	.9507	10.184	.903	3.387	.637	.363
10	.9975	1.0000	10.776	2.054	2.874	.546	.454
		6.0726	52.208	M'_2	M'_1	V_2	V_1

ARCH NO. 19.

Base: $l = 72$; $f = 17.37$; $f \div l = 0.2411$; $D' = 0.6569$; $K' = 0.807$; $\Sigma M'_1 = -16.378 + 23.531$.

Point No.	y'	Δ'	H'	M_1'	M_2'	V_1	V_2
1	0.1226	0.2534	0.000	−1.000	0.000	1.000	0.000
2	.3203	.3213	.515	−2.368	.280	.991	.009
3	.4956	.3891	1.485	−3.188	.777	.972	.028
4	.6315	.4797	2.816	−3.301	1.415	.943	.057
5	.7421	.5702	4.395	−2.980	2.100	.902	.098
6	.8302	.6652	6.084	−2.249	2.735	.850	.150
7	.8987	.8010	7.728	−1.234	3 220	.786	.214
8	.9488	.8824	9.152	−0.058	3.451	.713	.287
9	.9816	.9322	10.205	1.117	3.360	.631	.369
10	.9983	1.0000	10.773	2.152	2.924	.544	.456
		6.2945	53.153	M'_2	M'_1	V_2	V_1

ARCH NO. 20.

Base: $l = 40$; $f = 10.6$; $f \div l = 0.265$; $D' = 0.5858$; $K' = 0.821$; $\Sigma M'_1 = -16.311 + 25.443$.

Point No.	y'	Δ'	H'	M_1'	M_2'	V_1	V_2
1	0.1274	0.2180	0.000	−1.000	0.000	1.000	0.000
2	.3396	.2784	.519	−2.372	.206	.992	.008
4	.5056	.3519	1.473	−3.151	.805	.974	.026
4	.6415	.4379	2.899	−3.348	1.472	.946	.054
5	.7500	.5364	4.431	−3.009	2.219	.906	.094
6	.8367	.6448	6.169	−2.252	2.914	.854	.146
7	.9038	.7794	7.876	−1.179	3.455	.791	.209
8	.9509	.8595	9.360	.058	3.724	.717	.283
9	.9727	.9613	10.473	1.304	3.658	.634	.366
10	.9981	1.0000	11.024	2.362	3.176	.545	.455
		6.0676	54.133	M'_2	M'_1	V_2	V_1

PLACING STREET RAILWAY TRACKS in a special reserved portion of the street is suggested as an economical measure by Mr. Robert H. Haynes, M. Inst. C. E., Borough and Water Engineer, Newport, England. The suggestion is made in the course of a paper on "Town Planning" submitted to the Incorporated Association of Municipal and County Engineers on May 11, 1910. We quote the paragraph in which the suggestion is made as follows:

There is much to be said for the continental system of multiple track roads. The general adoption of this method in main arterial roads would have an extraordinary effect on transportation methods and costs. If tramway tracks were placed in a special place reserved for tramway traffic alone, the initial expenditure on track construction might be reduced by one-half and the maintenance rendered far more simple and much less expensive than can possibly be attained in the present systems of location and construction.

The Silt Problem: Kaw River.*

By HERMAN STABLER,† and HORATIO N. PARKER.‡

A knowledge of the burden of suspended matter carried by streams is frequently necessary in the practical solution of engineering problems. In connection with water-supplies for domestic or industrial use, irrigation-supplies without storage, and other operations in which a comparatively uniform quantity of water is utilized regardless of stage of river, the relative proportion of suspended matter in the water and the variation thereof with season and river stage are of principal importance. In connection with denudation, storage on a large scale, and other problems involving the entire flow of a stream, the principal items to be considered are the total quantity of silt moving in the stream and the variation thereof with season and stream flow. Errors of several hundred per cent. may easily creep into computations by reason of insufficient basic data, too cursory a study of the data available, and failure to distinguish between the above-mentioned two phases of the problem. The following study of the silt problem in the Kaw or Kansas River, at Holliday, Kan. (drainage area about 62,000 sq. mi.) is presented as an illustration of methods that may be used to avoid large errors of this nature. Absolute accuracy of results is not claimed, but it is believed that the data available have been utilized to their full practical value without drawing unreasonable inference and that the tabulations are of as much practical value for most purposes as if the basic data covered a much longer term of years.

The Kaw River system is composed of several large streams, chief of which, named in succession from west to east across Kansas, are Smoky Hill, Saline, Solomon, Republican, Kaw and Delaware rivers. The Saline and the Solomon are tributaries of the Smoky Hill. Kaw River is formed at Junction City, Kan., by the confluence of the Smoky Hill and the Republican. The Big Blue and the Delaware flow directly into the Kaw. The Kaw and its tributaries are rivers of the plains, though the headwaters of some of the streams originate in regions of rugged topography. Republican River is unquestionably the most turbid of the principal affluents of the Kaw and the one that carries the most suspended matter; then, in order, come the Delaware, the Big Blue, the Smoky Hill, the Saline, and the Solomon.

The basic data and computations of the study are: Stream flow at Lecompton, Kansas, 1900 to 1905, as determined by the U. S. Geological Survey, increased by one-seventh to represent conditions at Holliday; stream flow at Holliday, 1906 to 1908, estimated from gage readings of the U. S. Weather Bureau at Topeka, Kan., by means of a rating table constructed from corresponding gage heights at Topeka and discharge measurements at Lecompton increased by one-seventh; unpublished determinations§ from Dec. 29, 1906, to Dec. 31, 1908, under the direction of Prof. E. H. S. Bailey of the University of Kansas (made in pursuance of a co-operative agreement between the U. S. Geological Survey and the Kansas State Board of Health) of the relative proportion of suspended matter in samples of water from the Kaw at Holliday, taken daily and combined in sets of ten for analysis. The results of the analytical data, covering 72 periods of approximately ten days each, summarized as follows:

Suspended matter (parts per million).	No. of periods.	Per cent. of total number of periods.
More than 3,000	2	2.8
2,001 to 3,000	10	13.9
1,001 to 2,000	9	12.5
501 to 1,000	8	11.1
201 to 500	5	6.9
101 to 200	9	12.5
51 to 100	8	11.1
Less than 51	21	29.2

Maximum, 3,380; minimum, 13; mean, 744.

*Published by permission of the Director of the U. S. Reclamation Service.

†Assistant Engineer, U. S. Reclamation Service, Washington, D. C.

‡Assistant Engineer, U. S. Geological Survey.

§"Quality of Water Supplies in Kansas," by Horatio N. Parker; to be published by the Kansas State Board of Health.

TABLE I.—RECORD OF MEAN MONTHLY VALUES, SILT DETERMINATIONS, KAW RIVER, KANSAS.

Date, 1907-1908.	Suspended matter, parts per million.	Discharge, sec.-ft.	Total silt, tons.	Silt, tons per day.
January	84	4,460	33,600	1,085
February	263	5,470	118,000	4,220
March	1,500	7,260	987,000	31,900
April	284	4,760	115,000	3,830
May	303	4,540	126,000	4,070
June	1,500	7,200	935,000	31,200
July	1,990	9,200	1,582,000	51,100
August	606	5,280	303,000	9,780
September	114	3,420	39,700	1,320
October	404	4,330	174,000	5,620
November	34	3,080	8,450	282
December	23	3,650	6,640	214
January	28	3,590	7,960	257
February	169	4,180	62,900	2,170
March	210	4,210	81,800	2,640
April	162	3,940	53,100	1,770
May	2,670	15,600	3,920,000	126,500
June	2,230	65,800	11,520,000	384,000
July	2,170	24,200	4,470,000	144,000
August	1,800	16,050	2,480,000	80,000
September	396	6,680	427,000	14,200
October	506	4,060	163,000	5,260
November	335	4,090	108,000	3,600
December	63	3,930	21,300	688
Mean	744	9,130	27,743,450*	37,900

*Total.

Computation of the daily discharge in second-feet and of the total silt load in tons per day for each ten-day period was made. Comparison of discharge and relative amount of suspended matter shows:

(1) Generally suspended matter varies directly with discharge; but a general relation between the two will be in error by several hundred per cent. in many individual cases.

(2) Maximum suspended matter in any flood occurs considerably in advance of maximum discharge, and suspended matter for a given stage is generally greater on a rising than a falling stage.

(3) Relative variation is much greater in suspended matter than in discharge.

The detailed values, except as noted above, are not of sufficient interest to be reproduced here. The results were tabulated by months for further study and are presented herewith in Table I.

For convenience, the mean proportion of matter suspended in the water, in parts per million, will be referred to as "suspended matter," and the quantity of suspended matter in tons, tons per day, acre-feet, etc., will be referred to as "silt." Table I. shows the seasonal variation and the variation from year to year. It is interesting to note that the silt carried in the month of June, 1908, is 41.4% and the silt carried during the four months, May, June, July and August, 1908, is 80.7% of the total for the two years. The extraordinary influence of great floods in erosion and denudation is clearly shown.

The suspended matter and silt values show a more regular relation to discharge by months than by shorter periods on account of the averaging of eccentric results. When plotted, however, many wide variations from the mean curve are noticeable, particularly during low stage. So wide is the variation for suspended matter that a rating curve is practically valueless. A rating based on the mean monthly discharge and silt values is given in Table II. For discharge of 10,000 second-feet or more, this table will give results probably always within 50% of those obtained by actual measurement. For low discharge, however, errors of several hundred per cent. are likely to occur. There is a rapid increase in percentage accuracy with increase in discharge.

To study further the relation between discharge and suspended matter and silt, Table III., containing mean annual values, was prepared.

In Table I., the monthly silt values are in most cases within 7%, and in all but three months within 15% of what they would have been if calculated from the mean monthly suspended matter values. In the last column of Table III., is presented the ratio of actual mean annual silt to apparent mean annual silt as calculated from mean annual suspended matter. These ratios illustrate the wide error likely to be made by the use of a mean value for suspended matter, even though that value may represent a long period of time. A similar study on the Rio Grande gives for that stream a ratio of about 0.50, so it is to be understood that generalization in the matter of ratios is likely to lead to erroneous conclusions. The ratios in Table III. may be represented with a maximum error of 20% and a probable error of 7% by the formula:

$$\text{Ratio} = 1 + \frac{\text{discharge}}{10{,}000}$$

Of course, the treatment illustrated by Table III. does not assist directly in the estimation of the mean relation between discharge and suspended matter and silt for a long term of years. It does, however, give a wider range of annual values than is offered by consideration only of the two separate years covered by the suspended matter determinations, and in this way leads to better understanding of the relations between mean annual values than could otherwise be obtained. Plotting the values of Table III., fairly smooth rating curves are obtained. Table IV. is a rating table based on the curves.

The relations of Table III. may be represented somewhat less accurately by the straight line formulas: Silt = 6.8 (discharge — 3,300) with a maximum error of 18% and a probable error of 4.9%; suspended matter = .04 (discharge + 9,000) with a maximum error of 20% and a probable error of 7%. The accuracy of the table for discharges greater than 13,000 sec.-ft. is somewhat problematical, having been taken from extensions of the rating curves beyond the limits of the basic data. Nevertheless, the increasing accuracy of the curves with discharge and their close approach to straight lines indicate an accuracy as great for the extensions as for the known portions of the curves.

From the relations expressed in Table IV. and the computations for 1907 and 1908, Table V. was prepared.

If the means for 1907-1908 were used in place of the means for 1900-1908, there would be differences of 13.7% in discharge, 2.1% in suspended matter, and 20.8% in silt; and if the silt were calculated directly from the mean suspended matter, there would be introduced an error of 107%. If the results for the great flood year of 1903 were reduced by one-half, no nine-year mean would be changed by as much as 14%. It seems likely that the nine-year means are very close to the means for any long term of years.

A given weight of silt represents different volumes according to the proportion of voids associated with it in place. It may be assumed without great error that 100 lbs. of silt represents 0.61 cu. ft. of rock matter (no voids); 1 cu. ft. of soil (39% voids); 1.18 cu. ft. of sediment accumulated in a reservoir through a long term of years (48% voids); or 1.67 cu. ft., of freshly deposited sediment (63% voids). Taking the mean annual silt load as 47,820 tons per day, the equivalent denudation is found to be 282 tons per sq. mi. per annum, representing, on the foregoing assumptions, 1 in. depth of rock matter in about 682 years, or 1 in. depth of soil in about 413 years. The annual accumulation of sediment in a reservoir through a long term of years would be 9,430 acre-feet, or 15,210,000 cu. yds.; and the annual amount of freshly deposited sediment would be 13,300 acre-feet, or 21,550,000 cu. yds. The Kaw discharges into the Missouri a short distance below Holliday, and the deposition of a part of its enormous silt load in the Missouri and Mississippi is undoubtedly an important factor in connection with the maintenance of navigable channels in those streams.

TABLE II.—MEAN MONTHLY RATING TABLE, SILT DETERMINATIONS, KAW RIVER, KANSAS.

Discharge. sec.-ft.	Silt tons per day.
5,000	5,000
6,000	18,000
7,000	30,000
8,000	41,000
9,000	51,000
10,000	61,000
12,000	79,000
14,000	95,000
16,000	109,000
18,000	122,000
20,000	134,000
30,000	189,000
40,000	244,000
50,000	299,000
60,000	354,000
70,000	409,000

TABLE III.—RECORD OF MEAN ANNUAL VALUES, SILT DETERMINATIONS, KAW RIVER, KANSAS.

Year ending	Discharge, sec.-ft.	Suspended matter, parts per million.	Silt, tons per day.	Ratio.
Dec. 31, 1907	5,230	592	12,050	1.44
Jan. 31, 1908	5,150	587	11,980	1.47
Feb. 29, 1908	5,050	580	11,810	1.49
Mar. 31, 1908	4,790	472	9,370	1.54
Apr. 30, 1908	4,720	462	9,200	1.56
May 31, 1908	5,640	659	19,400	1.94
June 30, 1908	10,530	720	48,800	2.38
July 31, 1908	11,780	735	56,550	2.42
Aug. 31, 1908	12,680	834	62,400	2.19
Sept. 30, 1908	12,950	858	63,470	2.11
Oct. 31, 1908	12,920	866	63,440	2.10
Nov. 30, 1908	13,000	892	63,720	2.04
Dec. 31, 1908	13,030	895	63,760	2.02
2-year period	9,130	744	37,900	2.07

TABLE IV.—MEAN ANNUAL RATING TABLE FOR SILT VOLUME OF KAW RIVER, KANSAS.

Discharge, sec.-ft.	Suspended matter, parts per million.	Silt, tons per day.
4,000	225	3,700
5,000	545	11,200
6,000	685	18,600
7,000	720	25,900
8,000	748	32,800
9,000	773	39,200
10,000	797	45,500
11,000	821	51,700
12,000	845	57,900
13,000	869	64,100
14,000	893	70,300
15,000	917	76,500
16,000	941	82,700
17,000	965	88,900
18,000	989	95,000
19,000	1,013	101,200
20,000	1,037	107,400
21,000	1,061	113,600
22,000	1,085	119,800

TABLE V.—MEAN DISCHARGE, SUSPENDED MATTER AND SILT IN KAW RIVER AT HOLLIDAY, KAN.

Year.	Discharge, sec.-ft.	Suspended matter, parts per million.	Silt, tons per day.
1900	6,310	695	21,000
1901	4,190	285	5,000
1902	13,070	871	64,500
1903	21,600	1,075	117,300
1904	12,100	847	58,500
1905	12,550	858	61,300
1906	7,160	726	27,000
1907	5,230	592	12,050
1908	13,030	895	63,760
Mean 1900-1908	10,580	760	47,820
Mean 1907-1908	9,130	744	37,900

A PILE FOUNDATION IN LIGNITE characterizes a stone arch bridge over the river Neisse at Muskau, Germany. Steel or concrete piles were considered undesirable on account of the corrosive action of the material, so that wooden piles were used. But as these would not drive readily, and in any case the driving tended to break up the coherence of the lignite bed, it was decided to set the piles in drilled holes. Holes were drilled to a diameter of 10 to 11 ins., about 17 ft. deep, and when the piles were placed in they were driven by steam driver for a foot or two of further penetration, this being about the limit of driving. The work is reported in "Zentralblatt der Bauverwaltung" of April 30, 1910.

A NEW TYPE OF CONDUIT for underground electric cables has been recently placed on the market by the H. W. Johns-Manville Co., of 100 William St., New York City. This conduit is made of indurated fiber, a material which has been used very extensively for insulating purposes, such as third-rail coverings, controller linings, battery boxes, etc. Water pails, etc., have also been made of it for many years. The fiber is molded into shape at high temperature and pressure, and is claimed to be entirely without grain or lamination. An interesting feature of the new conduit lies in its bell joints. One end of each section is molded to an enlarged size—belled out—with an opening as large as the outside diameter of the opposite end of the next section. Thus, any two sections fit together without any reduction in the wall thickness of either section at the joint. This makes a stronger and more rigid connection than is possible with any other kind of joint. These joints may be of the short "socket," of the deeper "sleeve," or of a screwed type. To fit installations on a few systems, demanding straight joints without bell ends, the conduit is being made with the straight joint in which the jointed walls are of the usual half thickness.

The manufacturers claim that by reason of there being no seams or roughness at the joints of this conduit and as the air-tight joints prevent particles of concrete from seeping through, a No. 6 wire can be pushed through each duct from manhole to manhole, doing away with the ropes and rods so necessary with ordinary conduits. Tests made of this conduit with ⅝-in. thickness of wall shows that it has an average puncture voltage of 40,800 dry and 33,000 volts after 40 hours' immersion in water.

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The fuel economy of the locomotive and its efficiency in terms of the relation of power developed to fuel consumed are relatively low, due to the fact that a locomotive is an exposed and traveling power plant working under conditions which are necessarily very unfavorable to high economic results. In an editorial review of these conditions in our issue of Dec. 2, 1909, it was shown that (1) only about 45% of the heat in the coal is actually effective in evaporating water, (2) the steam consumption averages 25 lbs. per I. HP. per hour, and (3) only 70% of the work done on the pistons is effective at the rear drawbar of the tender. Combining these results it appears that only 2.75% of the heat in the coal appears as useful work in hauling trains.

Attempts to improve locomotive efficiency by a better utilization of the heat and the steam generated have been made in three directions: (1) by compounding, to get more work out of the steam; (2) by heating the feed-water, to utilize waste heat from the fuel or the exhaust steam; (3) by superheating the steam, so as to utilize waste heat and to give the steam special properties conducive to high economy. The first of these methods (that is, compounding) has been tried on a very extensive scale and was at one time very popular in this country, but for several reasons it has been practically abandoned within recent years. There is an exception to this in the Mallet duplex type of locomotive (with its two sets of cylinders driving two sets of driving wheels), which has come into extensive use in late years; but these engines are of an exceptional type intended for work of an exceptional character. Within recent years the second method (feed-water heating) has been tried experimentally in a number of cases and with promising results, as described in our issue of Dec. 2, 1909, but its use is as yet very limited and the possible gain in economy at greatest is not very large.

The third method (superheating the steam) has been tried by many roads and many engineers, using various types of apparatus. On very few railways, however, is superheating adopted extensively or in more than an experimental way. The two leading exceptions on this continent are the Atchison, Topeka & Santa Fe Ry. and the Canadian Pacific Ry. The former has about 150 locomotives equipped with superheaters, and has found the results of such practical value as to lead to the very general application of the system upon both new and old locomotives.

The type of superheater employed on the Atchison is notable for its simplicity, its freedom from interference with the construction and functions of the boiler, and for the ease with which it can be adapted to existing locomotives. It may be built as a separate apparatus or as an integral part of the boiler, both arrangements being illustrated elsewhere in this issue. It has another advantage in its large volume of steam space, in which the steam is compelled (by means of baffles) to come in close contact with a large number of highly heated tubes and consequently to absorb heat rapidly. On the compound engines it superheats the steam for both the high-pressure and low-pressure cylinders.

The system employed gives a moderate degree of superheat (about 100° of superheat, with steam delivered to the cylinders at about 450° F.). It is thus a medium between those aiming at high superheat and low superheat. The former involve special difficulties and may result in the deterioration of packing and cylinder metal. While the latter are mainly to be regarded as steam dryers, they have shown an economy in steam consumption, and also in boiler repairs due to the possibility of doing the same work with a lower boiler pressure.

Elsewhere in this issue we give considerable space to an abstract of a report issued by the mechanical department of the Atchison, Topeka & Santa Fe Ry., reviewing the general question of superheating and its development on this railway, and giving particulars also of comparative tests of engines with and without superheater equipment. It will suffice to say here that the superheater engine showed (1) an average saving in fuel of 13.3%, (2) an economy of 20.8% in fuel per 1,000 ton-miles, (3) a higher rate of combustion with lighter draft, and (4) a marked increase in evaporation. Furthermore, the engine can handle a heavier train, and yet start more easily and quickly on a heavy grade. In addition to these comparative tests, a test was made with another engine to determine whether a superheater of the type used could give a sufficient degree of superheat to produce satisfactory results. These tests showed that a practically constant or uniform superheat of approximately 100° could be maintained under all conditions of working, whether on an undulating profile, on a profile requiring the engine to work continuously to near its capacity, or when the engine was drifting considerably and using but little steam.

In this connection it is of interest to note that the Mallet type of locomotive, with its great length (on a flexible wheelbase) gives great facilities for the combined application of the three methods noted above for increasing the economic efficiency of the locomotive. The two independent sets of cylinders and driving wheels provide an almost ideal arrangement for compounding, while the great length available for the boiler (coupled with the inefficiency of excessively long boiler tubes) provides accommodation for both superheater and feed-water heater equipment. One railway has seen such an advantage in this type of engine as to convert consolidation (2-8-0) engines into Mallet engines of the 0-6-6-0 class, utilizing the additional length due to the new steam truck by extending the boiler shell to accommodate a feed-water heater. Another point of interest is the tendency to make all steam pipe connections on the outside rather than the inside of the smokebox, so that any leaks will be evident at once, instead of remaining undiscovered until they develop sufficiently to reduce the draft in the front end and so prevent the engine from steaming freely.

There are now pending in Congress two bills to establish a special court for handling appealed cases in patent litigation. These measures (Senate Bill 4982, House Bill 14,622) provide for a new court to sit at Washington and hear appeals in patent suits from the nine United States Circuit Courts in different parts of the country. At present, as some of our readers very likely know from unfortunate experience, the owner of a patent may have to prosecute infringements in nine different circuits throughout the United States, almost as if he had patents in nine different countries, in order to establish his rights. This is admittedly an extreme statement of the case, but as a matter of fact it has very frequently happened that a patent would be sustained on appeal by the court in one circuit and held invalid on appeal in another circuit.

The Committee on Patents of the National Association of Manufacturers, at the recent annual meeting of the Association, declared that the creation of a single court of patent appeals as proposed in these bills is the most important measure of patent law reform now before the public. The committee stated that the proposed law is the result of careful deliberation, extending over several years, by committees of the American Bar Association, the Commissioner of Patents, and many federal judges. The committee claimed that the present bill offers the soundest and most practical remedy for present conditions; that it would operate to diminish the cost of patent litigation and shorten its duration, so that the owners of patents, and manufacturers working under them, may find what their legal status is without the excessive expense and long delay at present required. The committee urged members of the Association to take up the matter individually with members of Congress, urging the immediate enactment of this bill.

Another matter on which the National Association of Manufacturers' Patents Committee reported relates to United States inventors who take out patents in foreign countries. At present, many of these countries require the invention to be worked within a certain limited time, under penalty of forfeiture, and also require payments of annual taxes. In the United States, on the other hand, compulsory working is not required, and patents are free of all taxation. The United States has already concluded a treaty with Germany under which American inventors taking out German patents are freed from the requirements as to compulsory working. Similar treaties are under negotiation and likely to be concluded with other leading commercial nations, which will free American inventors from the restrictions which have heretofore been imposed.

In our last week's issue we gave much space to the discussion concerning the conditions existing at Pittsburg with reference to the height of bridges over the Allegheny River. Reference was made in that discussion to a report just rendered to the Pittsburg Civic Commission by Col. Thomas W. Symons, Corps of Engineers, U. S. A., retired, and Mr. Frederick Law Olmsted. The complete copy of this report is of such interest that it should be secured by every engineer who is or may be directly interested in any litigation or controversy in which bridges and navigation interests are in conflict.

The report was prepared at the request of the Pittsburg Civic Commission, and, as stated in the introduction, the purpose of the Commission was to secure a report, from independent experts, which should weigh the interests of all parties in connection with the bridge question, and strike a balance between the claims of those using the bridges on the one hand and the claims of the river transportation interests on the other. The report of Messrs. Symons and Olmsted was passed upon by the Committee on City Planning on April 18 and was adopted by the Civic Commission on April 25. Many of the points brought out in this report were fully presented by Mr. Wilkins in his contribution in our last week's issue, but even greater emphasis may well be laid upon the extent to which it is possible to build boats to fit comparatively low bridges, instead of requiring bridges to be placed at a height to

accommodate any type of boat that any one chooses to build.

In the voluminous testimony and affidavits taken in the proceeding before the Board of United States Engineers in Pittsburg, an affidavit particularly deserving attention is one made by the late George S. Morison in 1903. Mr. Morison referred in that affidavit particularly to the enormous traffic on the Seine in Paris. The Seine is crossed, as every visitor to Paris knows, by a great number of bridges, most of them low masonry arches; and at high flood stages, as was evidenced by the very recent record-breaking flood at Paris, the headway under the bridges becomes so small as to stop navigation entirely. Mr. Morison in his affidavit, however, stated that a line of freight steamers runs between London and Paris, crossing the British Channel, and delivers its cargoes in the centers of the latter city, passing under at least half of the Seine bridges. These steamers have both their smokestacks and their masts arranged to be lowered for river navigation.

The conditions on the Seine are also referred to in the report of Messrs. Symons and Olmsted, and photographs are also shown of fixed bridges on German rivers with low steamboats and barges passing under them.

In view of what is actually accomplished on the continent of Europe, where inland waterway transportation has a magnitude that there is no prospect of its ever reaching in this country, it seems well to scrutinize the claims of the inland navigation interests, and inquire to what extent they are really justified by the public welfare.

The Design of Railway Tunnels with a View to Economy in Maintenance and Operation.

The designing of railway tunnels involves the consideration of a much larger number of factors than might seem apparent at first sight, but neglect of these may result in trouble and expense in the future history of the tunnel. The factors to which we refer more especially are those which relate to the operation and maintenance of the tunnel; they are to a large extent distinct from those which relate to the determination of methods of construction, but are apt to be given less weight or consideration than the latter. In planning a structure of this kind there is sometimes a tendency to regard it rather as a work of construction in itself, than as an integral part of a railway and built solely for the purpose of carrying traffic. But with all due allowance for the importance of carefully planning the construction, it may be said that the greater the permanent economy of the finished tunnel in its maintenance and in the operation of traffic through it, the more nearly will it come to the economical fulfilling of its purpose. In other words, a relatively high cost of construction may be warranted if it will result in economy of maintenance, and in economy and efficiency of operating traffic over the railway.

In the first place there is the cross section to be determined, both as to its form and its dimensions. This is considered usually in regard to the material tunneled, the cost of construction and the necessary clearance for trains. Other matters which should be considered as affecting the future use of the tunnel, but which are sometimes neglected, are the relations of the cross section to the drainage and ventilation, the operation of traffic, and the maintenance and repair of the roof arch. Allowance must be made also for a reduction of the normal clearance by gradual deformation of the lining. This may result from the settling (more or less irregular) of the roof, the inward movement of the side walls under pressure, or the general settling together of the masonry.

It may be regarded as axiomatic that it is rarely advisable to adopt the minimum possible section on account of saving in cost of construction. The slight saving is likely to be greatly counterbalanced by the future cost of watching, maintenance and repairs; while repair or reconstruction (whether in part or in whole) of a tunnel under traffic is difficult, costly and dangerous work. This question of cross sectional dimensions and area is included in a recent report, an abstract of which is given elsewhere.

The proper form of section will depend largely upon the character of the material excavated, approximating more nearly to a circular form with increasing softness or wetness of the material. It may be noted, however, that the horseshoe section which is very generally used abroad in loose and soft material, is less common in this country, where greater reliance is placed upon the stability of vertical side walls. A discussion of this matter, with formulas for design of cross sections to suit different materials, will be found in "The Railway Engineer" (London), April, 1909. This article contains the following statement, and implies that many tunnels which are not designed on the lines of theoretical investigation are uneconomical structures, due to the use of an excessive amount of masonry:

> It is not that absolute and exact forms are always essential. In some cases the exact form is essential. Where this is the case, and the correct form is not carried out in construction it often happens that no evil results follow. The reason is that engineers who ignore the correct forms and yet do sound and safe work by experience have probably found that a certain thickness of masonry is necessary to secure stability. What they have really carried out by experience is to build the walls so thick that the correct form of the tunnel can be drawn within the masonry.

If the form of the tunnel cross section is unsuitable to the proper resistance of stresses due to the material surrounding it, the tunnel is likely to be expensive in one of two ways: (1) if built heavy enough to resist these stresses, it has probably an excessive amount of material; or (2) if it is not heavy enough to resist these stresses its maintenance in proper condition will involve watching and repair work, with constant anxiety on the part of those in charge, and the prospect of eventual reconstruction at heavy expense and considerable difficulty. The proper design must depend upon a combination of good judgment, experience, careful investigation of local conditions, and the wise use of theoretical methods or formulas. An undesirably small limit of clearance in tunnels, especially in old tunnels, may be due in a measure to an increase in dimensions of rolling stock equipment, so as to come more closely to the theoretical clearance lines. On curves especially, the cross sectional dimensions of cars, and also their length, may tend to reduce the actual clearance at certain points.

When a tunnel is located on a sharp curve, another condition has to be taken into account. It will be necessary to consider whether the normal section (for tangents) will give sufficient clearance to cars when tilted by the superelevation of the outer rail. It may be sufficient to shift the track center outward from the center line of the tunnel to compensate for this inward tilting, or it may be necessary to enlarge the tunnel section. The latter is likely to be required for a tunnel of limited dimensions on a somewhat sharp curve and where very high freight cars or very long sleeping cars (which are also wide and high) are taken into consideration. (Engineering News, Sept. 9, 1909.) In this connection it is of interest to note that no enlargement is required for the spiral tunnels on 10° curves on the Canadian Pacific Ry. grade revision work in British Columbia (Eng. News, Jan. 23, 1908). The standard section for tunnels on this railway has a clear width of 16 ft. 6 ins. between side walls (or between the posts in timbered tunnels), with a semi-circular roof and a clear headway of 22 ft. 6 ins. above top of rail.

The reduction of grade on curves is general practice, in order that the combined train and curve resistance will not exceed the normal train resistance on tangents. It is a much less common practice to reduce the grade through a tunnel, although it is done in very many cases. The object is to compensate for the reduced adhesion due to the slippery condition of the rails (which usually prevails in tunnels), and for the extra head resistance due to the confined atmosphere. Without such compensation, the engine will have to work exceptionally hard, and there will be the possibility of a heavily loaded engine being stalled in the tunnel. With heavy working under such conditions, the blast from the smokestack may cause injury to a permanent roof lining or may result in setting fire to a timber lining by the sparks ejected. The volume of smoke and gases also causes objectionable conditions.

If a ruling grade was carried through a tunnel without reduction, the maximum resistance would occur in the tunnel due to the atmospheric head resistance and the decrease of adhesion on the damp rails. This would be a most undesirable condition. On the other hand, a certain grade is necessary for proper drainage, and usually also for ventilation. Mr. W. L. Webb in his "Railway Engineering" states that a grade of at least 0.2% is needed for drainage.

The lining of the tunnel is another important consideration, and practice varies, of course, in regard to both materials and thickness, depending largely upon the character of the geological formation. In solid hard rock, it is very general to leave the work unlined, but as there is always more or less liability of falls of stone, careful watching is necessary. In fact, where there is heavy traffic the lining of the roof is a wise precaution against accidents or delays to traffic. Lining is necessary for tunnels which intersect rock strata of steep inclination, or are in rock which disintegrates with exposure.

As to the materials of the lining, concrete and brick are most generally employed, with stone less frequently. Concrete blocks have been employed in a few cases. Where brick is used for the roof, the portion of the arch directly over the track should have vitrified brick laid in cement mortar which is allowed ample time to become thoroughly set and hard before being subject to the blast from the locomotive. Otherwise, the joints are liable to be cut and the lining eroded. With concrete arch lining also, the concrete should be given ample time to set, or it may be eroded and disintegrated by the action of the blast and the gases. In several tunnels of the Wabash-Pittsburg Terminal Ry., water (from abandoned coal mines) highly impregnated with sulphur had a serious disintegrating effect upon the concrete lining. It has been suggested that this might have been prevented by an outside course of brick laid in bituminous cement. On the other hand, it must be borne in mind that it is difficult to get such protective work done effectively under the cramped and uncomfortable conditions of tunnel construction. In exceptional cases, as in swelling ground, steel ribs may be necessary to reinforce the lining and enable it to sustain the pressure.

When a temporary timber lining is used, to be replaced later with a permanent lining, one question to be considered is whether to give the excavation (1) sufficiently large dimensions to admit of placing the permanent lining inside of the timbering, or (2) a smaller cross section which will necessitate the removal of the timbering or else allow only a minimum thickness for lining inside the timbers. The former practice (that is, the use of a large cross section) was adopted in the tunnels on reconstruction work on the Southern Pacific Ry., as described in our issue of Dec. 6, 1906.

The thickness of tunnel lining is determined more by practical experience and observation than by formulas. An assumption often made is that the mass to be supported is that contained between planes extending at 45° from the tunnel, but in Patton's "Civil Engineering" it is stated that the pressure is not proportional to the depth below the surface, as above a certain limited height from the arch the earth is self supporting. The conditions existing around a tunnel, however, are such that theoretical considerations can be regarded only as a guide. The material above the tunnel is rarely of uniform character, and its condition at any point is problematical. Slight slips of the strata or the percolation of water may cause unexpected eccentric or excessive pressures at certain points. In some cases also, a flow of water over the roof may wash out loose material, resulting in large or small cavities which may cause a sudden drop of material upon the arch.

Another purpose of the lining is to keep the tunnel dry or waterproof, but in very many cases this purpose is fulfilled imperfectly. The water is

likely to be under pressure, and therefore will persistently seek any weak spot. Such spots are very liable to exist, owing to the difficulties of tunnel construction work. A common practice is to plaster the extrados of the arch with a cement or bituminous coating, but this is frequently punctured and broken by the packing, placed to fill the voids between the arch and the excavation. A plan which has been adopted with brick lining is to place the waterproof course under the last ring, which thus forms a protective covering. Methods of waterproofing and strengthening the linings of new and old tunnels were discussed in our issues of Nov. 25 and Dec. 23, 1909.

The waterproofing of the tunnel has an important bearing also upon the drainage. Most tunnels are "wet" to a greater or less extent and have water seeping through the masonry or entering through drains and weep-holes. While such drains are designed to relieve the hydraulic pressure due to water in the surrounding material, they tend also to cause washing and flow in that material, which may culminate in serious movements of the ground. For this reason Mr. Nivert, an engineer of the Paris, Lyons & Mediterranean Ry. (France), has advocated a thorough grouting and sealing of the tunnel lining and its backing, with a view to the absolute exclusion of water, any water in the soil being thus forced to find other outlets.

Ordinarily, however, as noted above, tunnels are wet, and the flow of a considerable amount of water must be provided for. This is not always an easy matter, owing to the width of the tunnel being insufficient for any but very narrow side drains, and the height insufficient to allow of drains under the ties. Opinions on this matter are quoted in another column. Improvement may be effected by lining the drains with concrete (so as to give a more free and rapid flow for the water), and also by taking some steps to prevent ballast from rolling into the ditches. Many standard plans for tunnels are defective in providing for a ballast slope whose toe is coincident with (or only a few inches from) the edge of the side ditch. With such construction the ditches will soon be choked with dirt and gravel or stone. It would be better to lay a tile drain in the ditch and carry the ballast over it, or else to build a stone or concrete curb wall at the edge of the roadbed to retain the ballast.

The ventilation of tunnels is a specially important consideration, as affecting the comfort of passengers and the handling of traffic, but frequently fails to receive its proper share of attention in the original design. The difficulties increase with the increase in number of trains, and if the provision made was barely sufficient at first, trouble may be expected in the future. In some cases it is difficult to obtain proper natural ventilation, owing to conditions of atmosphere and traffic, and artificial ventilation has been provided sometimes with great advantage, the resultant economy partly at least offsetting the first cost of the necessary plant. Ventilation is specially necessary where trains are frequent and where conditions are such as to necessitate heavy working of the engines, and perhaps the use of two or more engines to a train.

In many cases, especially where low-grade coal is used, the tunnel is practically filled with dense smoke and suffocating gases by each train. It may be undesirable or even dangerous to admit a second train for some considerable time, on account of the danger of asphyxiation of the employees, or that of collision with a former train which may have been stalled, but whose signals cannot be seen in the smoke. Such accidents are rare, it is true, but are a very real possibility and must be borne in mind in the design of a tunnel, especially for a line which will have a heavy traffic. On the other hand, the holding of trains at a tunnel to reduce such dangers is likely to upset operating conditions on the division and thus reduce economy and efficiency of handling traffic.

Troubles of this kind were formerly experienced in the Cascade and Port Huron tunnels, both of which are now equipped for electric traction. In both these cases also, it is to be noted that the traffic capacity of the tunnel has been increased in two ways by the introduction of electric traction. In the first place, heavier trains can be handled at higher speeds; and in the second place a greater number of trains may be handled in a given time, as the intervals between them are those required for safety in running, and there is no necessity of holding trains while the tunnel is slowly cleared of smoke and gas. In addition, there is the opportunity for improved conditions (including better lighting) for inspection and track maintenance work.

In a wet and gassy tunnel the rails are usually slimy and slippery. The moisture in combination with the gases (which it tends to precipitate) results in corrosion of the rails and fastenings, the softening and disintegration of the ballast, and the rotting of ties. These influences, added to the slipping of wheels and usually a minimum amount of ballast, all tend towards poor condition of track, with consequent increase in work and cost of maintenance and repairs. But as track maintenance in tunnels is difficult, slow, costly and dangerous, an endeavor should be made to reduce it. Sometimes it is impossible for track men and watchmen to enter the tunnel until some time after the passage of a train, on account of the smoke and gases, and much time is lost in this way. Thus ventilation has an important bearing upon the economy and efficiency of the track work. In long tunnels, also, it may be economy to provide electric lighting to facilitate the work itself and the movements of the men.

A radical method of reducing maintenance-of-way work in tunnels is that of providing a permanent track construction which will not require the continual attention and work required by the ordinary ballasted track. This matter was discussed editorially in our issues of Aug. 2 and Sept. 30, 1906, and the idea was put in practice in the new Bergen Hill tunnel of the Delaware, Lackawanna & Western R. R., at Hoboken, N. J., which was built in 1908-09. Here (as described in our issue of Aug. 19, 1909), each track has a concrete bed with pockets for creosoted blocks to which the ties are secured by screw spikes. Thus the work of surfacing and lining is eliminated, while in ordinary tunnels it requires continual attention and can rarely be done properly and effectively. With the concrete roadbed, the only work, except at long intervals, is that of inspecting the track to see that it is in safe and proper condition. The first cost of this permanent track construction (including the conduits for electric wires) was actually somewhat less than that estimated for the ordinary type of track, while the cost of track inspection and maintenance was only 8% of that for a neighboring tunnel having ordinary track.

From the foregoing general review of matters affecting the economics of tunnel design, it will be seen that these matters are all closely interrelated. Thus a heavy grade carried through a tunnel may result in excessive slipping of the driving wheels on damp rails (causing wear of rails and disturbance or disintegration of the track). The dampness may be due largely to insufficient provision for drainage and ventilation, and in combination with the gases from the engines it leads to corrosion of rails, splices and fastenings. If this tunnel is also of small cross-sectional area, additional atmospheric head resistance will be caused; and this, in combination with the reduced adhesion of the damp rails, will necessitate heavy working of the engines and may result in stalling trains in the tunnel.

Again, the volume of smoke and gases discharged in the tunnel by an engine working heavily under the above unfavorable conditions not only causes discomfort (and possibly danger) to passengers and employees, but may make it dangerous to send in another train until the atmosphere has cleared. Thus the tunnel may actually limit the operating capacity of the division.

Improvement may be effected by reducing the grade, enlarging the section, excluding excessive water, carrying off the normal water, and providing for improved natural or artificial ventilation. But all such work in tunnels carrying traffic is difficult and costly, besides involving an element of risk. Some idea of those risks and difficulties in emergency work may be gathered from articles in our issues of Nov. 25 and Dec. 23, 1909, describing the actual work of repair and reconstruction in a number of tunnels. With old tunnels, this work may be necessary and unavoidable. But in many cases, such work may be provided against by more thorough and careful consideration of the physical and operating conditions when designing the tunnel in the first place.

LETTERS TO THE EDITOR.

The Effects of Cooling a Boiler Furnace.

Sir: Referring to your editorial note attached to my second letter on this subject, appearing in your issue of May 5, p. 527, I infer that you conclude that those responsible for the tests in question considered the difference in CO_2 resulted from cooling the furnace. It was not my intention to intimate that the difference was due to such cause. Of course it was produced by a difference in air supply, which in one case was enough less to produce a difference in loss in hot gases fully equal to the difference in efficiency reported. If there is any doubt as to this fact, the loss in hot gases due to the reported percentage of CO_2 may be calculated and it will not be necessary to depend upon my statement.

In reference to the statement that analyses of the flue gases failed to show incomplete combustion, I will say that such analyses were not made and if they had been attempted, the appliances now available for that purpose would fail to show whether combustion was complete or not.

It is, of course, desirable to maintain a low furnace temperature within certain limits, but I would call attention to the fact, which has been demonstrated during a long experience, that when an amount of heating surface, equivalent to this case of a Heine boiler, having the entire one-half of the lower row of tubes exposed directly to the furnace, the water supply to the heating surface is usually inadequate with the result that tubes are readily burned. As a matter of fact, the tile roof was originally devised more particularly as a protection to the bottom tubes of this type of boiler, and I have found that it is necessary either to protect all of the heating surface, or else expose a very large amount to the furnace so that the distribution of heat shall not be concentrated.

In itself the report of the test in the bulletin in question is not especially significant, but harm is liable to come from the misconception of the argument presented, as it will tend to discredit use of the tile roof as a means of securing complete combustion, in those cases especially, where gases of the fire are discharged immediately among all of the tubes of the boiler in those types of apparatus differing in the design from the Heine boiler.

I trust that you will publish this letter as a closure to the discussion. Very truly yours,

A. Bement.

2114 Fisher Bldg., Chicago, May 11, 1910.

Sir: Communications in your issues of April 14 and May 5 relative to the conclusions drawn from a series of boiler tests and reported in Bulletin No. 34 of the Engineering Experiment Station make it seem desirable to explain somewhat more fully the data and considerations which lead to the conclusions questioned by your correspondent.

With regard to smokelessness, the conclusions of the Bulletin plainly state:

> The C-tile roof is superior to the T-tile roof in the matter of smokelessness . . .

The bulletin otherwise points out the limitations of the T-tile roof in this respect.

The contentions of your correspondent seem to be (1) that the smaller air-supply for the T-tile tests (as indicated by the observed CO_2 content) permitted a better heat absorption by the boiler entirely aside from any influence in this respect which might have been exerted by the uncovered tubes; (2) that the smaller amount or weight of gases passing and a higher temperature at the time of combustion made a more rapid heat transfer possible.

The test data indicate that the difference in temperature between the water and the gases was, in general, less during the T-tile tests than during the C-tile tests. The more satisfactory heat transfer was made then without, rather than in connection with, large temperature differences. It must have been due to other causes. The greater amount of exposed heating surface and its advantageous position for the purpose of heat transmission during the T-tile tests offers an explanation of the temperatures noted and of the more satisfactory heat transfer which occurred. The time, or length of path, during which combustion was completed was also probably influenced by the kind of roof and this in turn influenced the temperatures throughout the furnace and combustion chamber.

Comparison of individual tests might be made where the weight of air-supply is the same for the T and C-tile tests, also where the weight of air-supply for a single T-tile test is greater than for a single C-tile test. The temperature and efficiency differences would, however, in each case have the same general relations as were shown by a consideration of the averages for the eight tests. The accompanying table presents comparisons of individual tests along such lines.

The differences in weight of gases per pound of fuel, when considering the individual tests, are not accompanied by corresponding differences in flue temperatures such that air-supply can be used to satisfactorily explain the differences with respect to efficiencies. The slightly lesser average weight of gases per pound of fuel for the T-tile tests can by no means be considered as the only or as the principal cause of the variation in efficiency. A comparison of individual tests where the CO_2 content is exactly the same exhibits the same characteristic differences as has been called attention to from a comparison of the averages. It might be pointed out that three of the C-tile tests have a higher CO_2 content than one of the T-tile tests. The T-tile test has, however, a higher efficiency than any of C-tile tests. Such comparisons indicate that the slight CO_2 differences as determined in these tests cannot be considered as indicating the cause of the differences in efficiency.

If an estimate (along somewhat theoretical lines) were made of the chimney losses assuming that the entire difference in results between the two series of tests was indicated by the 0.7% difference in CO_2 content and the difference in temperature of the exit gases, it would be found that a much greater proportion of the difference might be ascribed to the temperature difference than to the CO_2 difference. That is, the difference in temperature of the escaping gases was the important factor in affecting (or explaining) efficiency differences. It is hardly necessary to say that the temperature of the exit gases may vary from other causes than amount of air-supply. Radiation, amount of heating surface, or the readiness with which it transmits heat (which are the points in question) are most important factors.

For the tests in question it seems reasonable to conclude that the exposing of a considerable amount of heating surface directly over the fire, resulting in a better heat absorption and a smaller radiation loss, was the principal cause of the increased efficiency during the T-tile tests.

Very truly yours,

J. M. Snodgrass,
Assistant Professor of Mechanical Engineering,
in Charge of Fuel Tests.

Engineering Experiment Station, University of Illinois,
Urbana, Ill., May 16, 1910.

COMPARISON OF INDIVIDUAL BOILER TESTS FOR RELATIONS OF CO_2 CONTENT. (AIR SUPPLY.)*

	Test No.	Kind of tile.	CO_2 content, %.	Efficiency (boiler), %.	Efficiency (plant), %.	Temperature of exit gases, °F.
CO_2 Content The same	3c	C	7.7	65.92	61.97	563
	2t	T	7.7	69.45	67.49	484
	3t	T	7.7	67.45	66.10	458
CO_2 Content Greater for the C-tile tests.	3c	C	7.7	65.92	61.97	563
	1t	T	6.7	68.56	65.43	496
	1c	C	7.5	66.28	60.51	549
	1t	T	6.7	68.56	65.43	496
	4c	C	7.0	65.79	61.92	556
	1t	T	6.7	68.56	65.43	496

*This table presents six of the eight tests reported (omitting one C-tile test and one T-tile test having CO_2 determinations of 5.1 and 7.9 CO_2, respectively). If averages be taken for these six tests the three C-tile tests will be found to have as high, or slightly higher, CO_2 content than the three T-tile tests. The average flue gas temperatures and efficiencies will, however, be substantially the same as corresponding averages for the eight tests reported.

[With the publication of these two letters, we believe that the discussion of the boiler trials at the University of Illinois and of the claim that a slight cooling of a boiler furnace can result in increased economy should end as it has been carried to such a point that our readers are now able to decide on the merits of all points in contention.—Ed.]

Bank Revetment on the Lower Mississippi River.

Sir: The paper by Mr. John M. Sweeney, printed in Engineering News of May 5, relating to the subject of western river navigation, contains much information of an interesting character.

The writer wishes to offer some comments on one phase of the subject as treated by Mr. Sweeney, to wit, terminal facilities for handling river traffic.

There can be no doubt that in this feature lies the heavy handicap upon river traffic in competition with railroad carriage of freight. Along the lower Mississippi all river freight is now handled in the same crude fashion that prevailed fifty or sixty years ago. At all way landings all manner of freight is carried on the shoulders or by the hands of negro "roustabouts," from the deck of the boat to the top of the bank, which at low stages of the river involves a climb, usually up a steep bank of 30 ft. or more vertically. The bulk of this freight is handled at night and in all sorts of weather.

At the cities and ports where there are "wharf boats," the task of unloading as well as loading steamboats is much easier; but the unloaded freight must all be carried on drays to the top of the bank by mule power.

Mr. Sweeney presents two alternatives as a possible recourse in the solution of the freight handling problem; (1) fixed terminal structures erected on the river bank, with apparatus for hoisting the freight from the boat below; and (2) the use of wharf boats as landing and storage places, which adjust themselves to the varying stages of the river. The latter method still leaves all freight to be hauled by mules, up steep inclines, in some cases 40 to 150 ft. in vertical elevation.

Mr. Sweeney points to several fixed terminal structures now in use along the Ohio River for placing bulk freight, but thinks that no way can be devised for loading and unloading miscellaneous freight with facility by mechanical means; and says, referring to former times, "with the exception of some attempts at Memphis, no special appliances were used for handling merchandise freight," etc.

The main purpose of this paper is to bring forward a fact, and a factor in this problem, now to be stated, to wit: whatever opportunities there may be for establishing fixed terminal facilities for river traffic along the Ohio River, no such opportunities exist anywhere along the Mississippi River between Cairo and Baton Rouge, La.; and this is owing solely to the instability of the river banks. This applies to points where there may be local stability, as well as where the bank is actually caving into the river.

Mr. Sweeney's remarks about attempts at handling merchandise freight at Memphis by mechanical means indicate that he is but imperfectly informed about that episode in the history of river traffic. As a matter of fact, early in the seventies of last century two large general freight elevators were erected, one at Memphis, Tenn., and the other at Vicksburg, Miss. It is believed that these structures were built by the Anchor Line Company, of St. Louis, then running important lines of steamboats between St. Louis and New Orleans, consisting of a number of large packet boats. The writer has personal knowledge that these two elevators handled a very large volume of miscellaneous freight, apparently with perfect facility. The structures were built on series of piles, reaching from the top of the bank out to low water. The main floors were about the same level as the contiguous streets. The freight was brought up from the boats on endless "chains" that were adjustable to the varying stages of the river. There were no contiguous railroads at that time, but the drays were driven into the building and there loaded, the merchandise being in assorted piles on the capacious floor space.

In the year 1876, the caving of the river bank then going on in a locality five miles above Vicksburg resulted in a "cut off," which speedily removed the channel of the river to a distance of a mile from the elevator, and its usefulness was entirely destroyed.

A few years later, the caving in Hopefield bend a few miles above Memphis, resulted in the filling of the channel in front of that elevator with sand and mud, and it also "went out of commission." About that time the Anchor Line went down, it was reported at the time, and generally believed, by sale to the Illinois Central R. R. Co.

It is certain that at that era in the history of interior transportation, the railroads were making strenuous efforts to run down river traffic and appropriate all the business to themselves. Since then, however, the country has been confronted by conditions wherein the railroads had not the capacity to handle all the traffic offered them, and railroad managements have latterly declared in favor of river improvement and a revival of river transportation.

As regards the Mississippi River below Cairo; if river traffic is to be revived and grow to considerable proportions, the first necessity is that stability shall be given to the banks of the river. Under present conditions it is not safe to erect a permanent and costly terminal structure at any point along this part of the river, because there is always danger that active caving conditions even somewhat remote from the building, may set up such changes in the position of the river channel as to destroy its usefulness; and not even freight shelters can be maintained at most of the way landings, as the localities where steamboats can approach the shore are nearly all on caving bends. Furthermore, when the river reaches a stage a little over the bank, traffic must be suspended at that landing until the water recedes; and these conditions often last for several months in the winter and spring seasons. At important ports where wharf boats are in use, there is still the necessity of hauling all freight by mule power, up steep inclines, and in some cases to considerable elevations, which constitutes a heavy burden on the traffic.

As above stated, the first requisite—and it is a sine qua non, for placing the traffic of the lower Mississippi River on something like an equal footing with the railroads—is that stability shall be given to the caving banks along this part of the river channel.

In this connection it is gratifying to note that both the United States Congress and the Mississippi River Commission have recently assumed an attitude favorable to entering upon a general policy of revetting all the caving banks along the lower river.

The appropriation for the improvement of the Mississippi River now pending in Congress, in the rivers and harbors bill, contains for the first time, at least for many years, a distinct recognition and approval of this policy, with the intention expressed, as reported, that a considerable portion of the money appropriated shall be so expended, and the policy continued in the future.

While the amount now provided for this purpose is relatively small, yet it is enough to enable the River Commission to make a fair beginning and accomplish much good, and is exceedingly valuable as defining a policy of permanent improvement of the lower Mississippi River, which policy it is to be hoped shall be persisted in.

Let all the caving banks be given permanent stability, and all else that is needful for the easy navigation of the lower river must follow in logical sequence, including a much improved and reliable channel for navigation.

That it is entirely practicable to accomplish this object has been already demonstrated by the work of the River Commission in the application of brush mattress revetment for the prevention of "cut offs," the protection of harbors, and other local purposes.

The problem then resolves itself into the simple questions of time, and money. The writer has made an estimate, based upon various reports of the Mississippi River Commission, of the cost of revetting all the caving banks, and adjunctive works, between Cairo and Red River, Louisiana, at $75,000,000, which he believes to be a fairly liberal estimate. If this sum is expended in twenty annual appropriations the burden upon the national treasury will be very moderate when the great value and importance of anticipated results is considered.

T. G. Dabney, M. Am. Soc. C. E.

Clarksdale, Miss., May 11, 1910.

[Mr. Dabney's ideas appear to be directly in line with the policy advocated by Mr. R. S. Taylor of the Mississippi River Commission in our issue of May 5.—Ed.]

Efficiency in Engineering Education.

Sir: I have read with unusual interest Prof. Swain's address on "Limitations of Efficiency in Engineering Education," published in your issue of May 12.

For about twenty years I have been an employer of engineering college graduates. Based upon this experience, I am able to express entire agreement with Prof. Swain's position with reference to engineering student life and I think also that as a very general proposition Prof. Draper is entirely right when he says, "With an independent, sane, balanced character, having the elements of success anyway, the advantage of a college training cannot be over-estimated."

One portion of the address that especially appealed to me is that referring to those who are by nature unfitted for engineering work. How often have I listened to the confessions of graduates who were no longer wanted: "I never did like the work anyhow," "Father or Mother wished it," etc.

From an employer's viewpoint there is one branch in engineering education which I believe warrants specific attention. It is teaching the habit of accuracy. We find our greatest difficulty with young engineers to lie in the fact that they are not schooled to exact work. We give them work to do and 95% of their calculations may be quite correct (more often this percentage is nearer 75); but all are of no value because 5% of the work is wrong. These students may understand principles and formulas quite well, but in the ordinary mathematical work incident to their application they show a disastrous deficiency in accuracy. This deficiency is evidenced in the simple mathematics necessary in estimate work.

I have often thought that I would like to see an experiment tried in the development of accuracy in young student minds. What I would first do would be to have an hour each day in accuracy demonstration. I would have the young men go to a blackboard with half their class at a time as an audience. At the blackboard they would be given unexpected long problems to publicly work out and I would begin with the simple addition of long columns of numerals and work up to more difficult tasks as fast as the simpler ones were mastered. I have been astonished to see how few men can add correctly a column of figures even if given the opportunity to check their work.

Absolute accuracy and reasonable speed are often sadly lacking and if the foregoing or some better drill would correct this deficiency, a long step forward would result.

If to-day I wanted five college graduates from a school and could send the graduating class to a blackboard for say two hours, I would, other things being equal, make my selection from those who made high accuracy records,

feeling sure that such minds would be capable of concentration and logical reasoning from cause to effect, and would have a good capacity for daily successful achievement.

I think that a fellow who showed an average of 98% in accuracy would be worth about $25 per month more to start with, than the student showing 94%, other elements being practically the same.

Yours very truly,

Hugh L. Cooper.

60 Wall St., New York, May 17, 1910.

Sir: It is with considerable interest that we at this time read Professor Swain's very valuable and opportune paper on technical education. On the whole I believe that Professor Swain's views will be generally accepted, although I venture to disagree with some of them in perhaps unimportant details.

Professor Swain says in effect that colleges are not commercial institutions, and in the ordinary sense of the term this, of course, is true, inasmuch as they are not operated for financial gain. But aside from that, I believe that a college will differ but little, if any, from a business concern.

In internal management, accounts, and office systems, colleges should conform to the latest and most approved methods in use in commercial institutions. In case of a manufactured article the manufacturer's moral responsibility for it does not cease with its sale. So the responsibility of the colleges for their graduates does not end at graduation but continues through life.

Colleges should graduate only those students for whom they are willing to assume responsibility, and should engage only those instructors to whom they can obligate themselves without decreasing the output. How this is to be accomplished appears to me to be not so very difficult of solution.

A certain standard of instruction governing each course, or subject, should be officially adopted and to this standard the instructors should be required to conform without deviation. In the method of conducting their classes the instructors should be given as much liberty as possible. But the final examinations, both the formulating of the questions and the marking of the papers, should be taken out of their hands and put into the hands of a committee appointed by the head of the department. This will assure that the standard is maintained and that there is no partiality shown in the grading, which is otherwise a difficult thing to avoid.

A certain percentage of students will be almost certain to fail and this number should be allowed for. But, if after making this allowance the required number fail to pass, then the fault is with the instructor, provided sufficient time has been allotted to the course, and there should then be no difficulty in removing him from that course.

In college work this matter should be almost automatic, as in commercial, the man who does not make good should expect his removal as a matter of course. But there is nothing definite on which to base such action unless the final examinations are conducted by a committee governed by the standards in force.

Even the best of men must on entering any line of work be trained in the routine of that particular line of business. I believe the colleges can train their new instructors to become efficient teachers and they can certainly assist them in many ways to gain efficiency.

It is necessary, of course, to inspire the confidence of the public in the value of your output, the college graduates. I believe that one reason for the lack, in some instances, of this public confidence in college education is the absence of any known standard of instruction. It is publicly known that a large number of students are year by year given a diploma and a degree after pursuing a course of study along various lines. But it is not known what the standard requirements are before that degree can be obtained. The college catalogs do not shed any light, as they ought to do, on this subject.

Some European schools officially publish in the press the final examination questions after each examination. This is a procedure which I believe could be adopted profitably in this country, such publication in the technical or educational press to be supplemented with a statement of the standards in the college catalogs.

General knowledge of what these standards are, coupled with the known stringency with which they are maintained will have a marked tendency to inspire universal confidence in the efficiency of our colleges.

Again, the practice which has lately come into vogue of conferring honorary degrees for mere temporary popularity has brought college degrees into popular contempt.

Unless the colleges have the public confidence, their graduates will be looked upon with a suspicion which, even if unjust, is a serious handicap.

By the adoption of the above, namely: (1) the establishment of certain rigid standards governing each course and each subject; (2) placing committees in charge of the final examinations; and (3) general publicity about what these standards are and the rigidity with which they are enforced, it seems to me that there ought to be little difficulty in increasing the efficiency of education to any desired degree and in retaining the public confidence in these institutions.

Yours very truly,

Anton S. Rosing,
Asst. Professor of Civil Engineering,
Michigan Agricultural College.

East Lansing, Mich., May 18, 1910.

Sir: The engineering world and the public in general owe you a vote of thanks and appreciation for the publication in your issue of May 12 of Prof. Geo. F. Swain's admirable presentation of the "Limitations of Efficiency in Engineering Education" in his address at the opening of the Carnegie Engineering Building at Union University.

The present defects and the possible remedies are so well shown in Prof. Swain's address, that a careful reading of the same is the duty of every progressive engineer as well as every educator.

You state editorially that "Nowhere have the defects of methods still too common been more clearly exposed. Nowhere have the proper methods for instruction and organization been more admirably stated."

This may be true, referring strictly to technical education. Prof. Swain states, however, that "many of my remarks apply of course with even greater force to the college graduate also." Bearing in mind the applicability of Prof. Swain's "defects and remedies" to education in general, technical or otherwise, I wish to note one exception to your editorial statement quoted above.

For four or more years past President Woodrow Wilson of Princeton University has been talking openly to the educational world and the public, reiterating the very defects in general college work that Prof. Swain has here applied to the work of engineering schools, and advocating the very remedies so strongly recommended in the address in question. And it has been not only talk, for many of the reforms have been actually carried out through all departments at Princeton, and so effectively that the standard of scholarship has been notably increased, and the enhanced efficiency of the University shown in the improved product, even in the short space of four years.

Prof. Swain's advanced ideas upon the problems of present day education indicate forcibly the trend of our modern schools toward practical thoroughness and efficiency, and strengthen the position that he, with Woodrow Wilson, has taken—foremost among the country's educators.

Very truly yours,

N. R. McLure.

Phoenixville, Pa., May 18, 1910.

Sir: Of all the articles that have appeared in Engineering News for a decade on the technical schools, that of Prof. Swain is the fairest. Every line bristles with facts and sound sense. Although a teacher, he has certainly gone as far as most of the skeptics in criticising the technical graduate and in admitting his deficiencies.

Among the many gems in Prof. Swain's article, is the statement that uneducated but successful men have sent their sons to college and thereby given them a worse handicap than they themselves ever had. Much stress has been laid upon the fact that employers are anxious to employ graduates. That's admitted and one of the reasons why this is so is that the graduates can be employed to start with for about their board while men with experience cannot be.

Another difficulty shown is that of getting good teachers and, what is more to the point, the impossibility of getting rid of bad ones. A large part of the article is devoted to suggestion for education of the teachers. This is certainly a good place to start. It is a pity so few teachers have had any actual experience in engineering work and I have never been able to understand why, with all their endowments, the colleges have not offered sufficient inducements to tempt engineers with established reputations for "doing things" to head their technical departments.

Mr. W. D. Taylor, present Chief Engineer of the Chicago & Alton, was a professor of engineering in the University of Wisconsin (I don't know why he quit) and I would venture a small bet that any of Taylor's graduates would not only know something but be able to do something as well.

By all odds, the best men to employ for an engineering party aside from skillful axemen are college boys. They are never "kickers"; they are always willing to work their best and put up with what comes without a complaint. They never make the chief any trouble; they don't quarrel among themselves or with any one else. They are workers with the party and gentlemen when in town.

It is to be hoped that Prof. Swain will give us some more articles on this subject. Every student in the country ought to commit this one to memory, and it wouldn't hurt the teachers to do likewise.

E. T. Abbott.

General Manager, Klamath Lake R. R. Co.

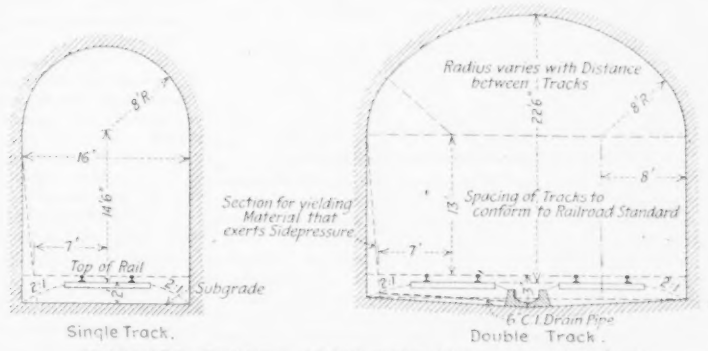
Pokegama, Oregon, May 2, 1910.

Railway Tunnels: Cross Sections, Grades, Lining and Drainage.*

The committee, as a result of its deliberations and of the examinations of a multitude of plans sent to it by various members of this Association, showing both recent tunnel construction and that of some years ago, begs to submit as a partial report the following:

We recommend the adoption, for single track tunnels on tangent, of a tunnel section with 22 ft. 6 ins. between the base of rail and soffit of arch over the center of track, and having a width between side walls of 16 ft. Where pressure against the side walls must be provided for, it will be advisable to reduce the width at rail top level to 14 ft. and to join this with the springing line width of 16 ft. with a curve of long radius. (See accompanying cut.)

When a tunnel is constructed on curved track, the tunnel section should be widened and the track displaced from the center of tunnel to such an extent as to give substantially the same clearance at the car floor level and at the car-eave level as is given on tangent by the dimensions recommended above.



STANDARD TUNNEL CROSS-SECTIONS RECOMMENDED.

For double-track tunnels we recommend the width to be that suggested for single-track tunnel plus standard width between track, and that the clear height above base of rail over the center of each track be 22 ft. 6 ins.

The arch for a single-track tunnel should usually be a semi-circle. The arch for a double-track tunnel should have the central portion constructed on a long radius and with short radii to connect the central portion to the side walls.

The size of the tunnel should not be varied for the different classes of track.† We consider the dimensions given to be the minimum for class "A" track. On account of the high cost of enlarging a tunnel constructed to less dimensions, and in view of the probability of all principal lines of railway soon needing roadways to support class "A" track, we believe the tunnel section for class "B" track and class "C" track should be constructed to conform to minimum dimensions for class "A."

We are not satisfied with the prevailing drainage in single track tunnels through side ditches, and favor some form of pipe drainage, but cannot make recommendation at this time as to what construction is best. For double-track tunnels we favor carrying the drainage down the space between the two tracks through a concrete channel, which may be covered with old boiler plate if desired.

We recommend that the rate of grade in long tunnels (and on their approaches) be lessened by 25% from that of the ruling grade so as to compensate for the greater resistance due to bad track, the less adhesion due to wet rail and to avoid the possibility of the train stalling in the tunnel with the resulting asphyxiation of the train crew.

We recommend the use of concrete for the permanent lining of tunnels requiring support. We recognize, however, that in certain conditions (as when the movement of the material is so rapid that concrete will not have time to reach a permanent set) a brick lining must be constructed. When brick is used, that portion of the arch for a horizontal distance of 5 ft. each side of the

*Abstract of the report of the Committee on Roadway, presented at the annual meeting of the American Railway Engineering and Maintenance-of-Way Association, held at Chicago, March 15, 17. The information as to the practice of different railways has been rearranged by classifying it under certain heads. The general subject is discussed in our editorial columns.—Ed.

†The Association has adopted a classification of track according to the character or amount of traffic carried.—Ed.

center line of track should be of vitrified brick laid in rich Portland-cement mortar.

Size of Tunnel Cross-Section.

PENNSYLVANIA LINES (Thomas H. Johnson, M. Am. Soc. C. E., Consulting Engineer).—We no longer have any single-track tunnels, but if I had to build one now I would make the section considerably larger both in width and height. Heretofore the dimensions of tunnel sections have been determined by considerations of clearance of trains and economy of construction. Experience in maintenance has shown us that there is need of additional height and width to provide ample room for centering when repairs to the arch are needed, as will be the case from time to time, and sufficient allowance for this should be made, over and above the clearance allowed for trains. Incidentally, it will afford better side ditches. In all cases the head room over center of track should not be less than 21 ft. to clear brakemen, and this will be compulsory in those states which have statutory enactments on the subject of head-room. These suggestions are offered for the consideration of the committee in formulating a section for recommended practice which should be larger than has heretofore prevailed.

CAROLINA, CLINCHFIELD & OHIO RY. (M. J. Caples, M. Am. Soc. C. E., Vice-President and General Manager).—In fixing the dimensions of our tunnels we sought to accomplish two results; (1) to provide headroom enough to enable a trainman to stand on the highest box car with safety; (2) to provide space enough to prevent the unpleasant results to passengers from smoke while passing through the tunnels, and in the longer tunnels to avoid asphyxiation of enginemen and trainmen when hauling maximum loads through such tunnels.

The writer has known of a tunnel where, by reason of its small section and notwithstanding the fact that the rate of grade was much less than on the grade approaching it, the train load had to be reduced 10% on account of the danger of asphyxiation of trainmen.

Tunnel Cross Section on Curves.

PENNSYLVANIA RY.—Unless the curvature on which a tunnel is built is heavy enough to materially cut down the clearance, we do not make any correction for curvature.

TRANSCONTINENTAL RY.—We make our single-track tunnels 16 ft. wide in the clear on tangents and 18 ft. wide on curves of 6°. On curves of greater radius, the width is proportional.

ERIE RY.—Tracks 13 ft. c. to c., spread 9 ins. on curves of 3° and over. The same for outside clearances.

CAROLINA, CLINCHFIELD & OHIO RY.—The standard width is 18 ft. clear for straight line and curves up to and including 8°. But for all curves the center line of track is shifted from center line of tunnel so as to equalize the clearance.*

MOBILE & OHIO RY.—Width 6 ins. greater than net clearance on tangents.

BALTIMORE & OHIO RY.—The standard width is 18 ft. for single track and 30 ft. for double track; semi-circular arch with side walls 14 ft. and 10 ft. high respectively, from subgrade (12 ft. and 8 ft. from top of rail). These dimensions are sufficient for clearance on curves up to 6°. No extra width will be required, but the center line of track will be eccentric with that of the tunnel to secure equal clearance of cars on both sides recording to speed limit elevations.

LEHIGH VALLEY RY.—Widen section to preserve clearance.

NEW YORK, NEW HAVEN & HARTFORD RY.—Section not increased unless curve is over 8°. Track is set over to outside of curve to compensate for elevation and keep top of cars symmetrical with center line.

NEW YORK CENTRAL RY.—Increase clearance on curves 2 ins. for each degree, plus additional amount necessary for superelevation.

SOUTHERN PACIFIC RY.—We make no change of section for curves, but set the tunnel over appropriately in reference to center line of track.† We consider it important to have ample distance between the center of track and the side walls, and use 8½ ft. as the minimum.

Grade Reduction in Tunnels.

LOUISVILLE & NASHVILLE RY.—Where tunnels are 2,000 ft., or more, in length, it is advisable to reduce the maximum rate of grade through the tunnel. A reduction of rate of grade of 0.2% is advisable, particularly if the rails are likely to be wet.

NASHVILLE, CHATTANOOGA & ST. LOUIS RY.—All our tunnels are on summits, with grades in both directions from the center. Where possible I would advocate reduction of grade through tunnels to avoid the heavy blast from the smokestack. The rate would depend on conditions and should be as small as possible to secure proper drainage.

*The tunnels were described in our issue of Jan. 21, 1909, and the arrangement on curves is identical with that of the tunnel section shown in our issue of Jan. 7, 1909 (p. 11).—Ed.

†Engineering News, Dec. 6, 1906.

CAROLINA, CLINCHFIELD & OHIO RY.—We reduce the rate of grade through tunnels if it is on a maximum grade against the traffic by 25 to 40%. If on a compensated grade in direction of traffic, we make no reduction. This practice may, however, be modified by special circumstances. The necessity for reducing maximum grades through long tunnels exists for the following reasons: (1) The possibility of asphyxiation of the train crew due to stalling a train in a tunnel is too great to be overlooked; (2) the possibility of damp rails reducing the adhesion; (3) the increased resistance to the passage of the train due to increased air resistance (similar to the plunger effect in a cylinder) unless the tunnel is of abnormally large section.

BALTIMORE & OHIO RY.—Where practicable, grade through tunnels is reduced as much as possible, but always made sufficient for good drainage.

LEHIGH VALLEY RY.—Tunnels should have grades as light as possible consistent with proper drainage and ventilation.

NEW YORK CENTRAL RY.—Grade in tunnels should be reduced; and should be about 0.06%.

NEW YORK, NEW HAVEN & HARTFORD RY.—Grade in tunnel should be reduced to about 25% of maximum grade.

SOUTHERN PACIFIC RY.—We do not reduce the maximum grade through short tunnels, being willing that the speed of trains should be slightly reduced in lieu thereof. Tunnels of any considerable length in our experience have been altogether built on special grades lighter than maximum, this generally being likely to be the case.

ERIE RY.—Grade in tunnels should be reduced to 25% or 50% of the maximum grade.

SOUTHERN RY.—Grade in tunnels should be reduced if practicable, the reduction being about 15%.

CHICAGO, ROCK ISLAND & PACIFIC RY.—The grade in tunnels should be reduced to not less than 50% of the maximum grade, and if possible the reduction should be extended for some distance from each end of the tunnel.

ATCHISON, TOPEKA & SANTA FE RY.—There is a 3½% maximum grade approaching the Raton tunnel, and the tunnel was built on a grade of 0.5%, so as to allow the cutting off of helpers, and so that one engine could easily take a train through the tunnel.

Tunnel Lining.

LOUISVILLE & NASHVILLE RY.—Cut stone masonry not preferred on account of the cost. Rubble stone masonry not as good as concrete. Choice between brick and concrete in some cases will depend upon whether brick can be had within reasonable haul. The cutting action of the sparks ejected from smokestacks on the soffit of the arch in the crown of the tunnel is less severe with Portland cement concrete lining than with brick. Where old tunnels are to be lined without interfering with train movements, as a general proposition brick lining is better, for the work can be interrupted or suspended with less detriment with brick lining than with concrete. Where the material through which the tunnel is driven is such as to develop sudden falls or slips it is best to use brick, when obtainable without excessive haul. With these exceptions the work can be expeditiously and economically done with concrete.

We use no formula for determining the thickness of masonry in lining, but are governed by our judgment.

NASHVILLE, CHATTANOOGA & ST. LOUIS RY.—We have a tunnel built in 1848 which was lined for a part of the way with brick, burned at the tunnel site at that time. On account of inferior foundations of the brickwork, it has been necessary for us to repair a large amount of this lining, but much of it remains just as built. It was laid with natural cement. The blast from the locomotive stacks cuts out the mortar from the brickwork, but we have found no efficient means of repairing this difficulty, on account of the fact that the cement could not harden in time to prevent the cutting.

Another tunnel is through solid rock, with some strata which disintegrate. We have had much trouble with rock at some points falling in, and inspect it carefully once a week, taking down all loose rock. We have not lined the tunnel for the reason that this lining has been postponed until it is double-tracked. My preference would be for concrete lining, provided it were possible to secure ample time for the cement to set before being put into use. Where this could not be secured, I would prefer brick, using hard-burned vitrified over points exposed to blast from the locomotive. Stone is too expensive for handling.

Have never used any formula for the thickness. Have found brick lining 18 ins. thick ample to support large falls from the caves above, where filling had not been properly done. This is ample for any single-track tunnel. Experience is preferable to formulas, which must necessarily be based on assumptions which could not be verified.

DENVER, NORTHWESTERN & PACIFIC RY.—In lining permanently I prefer concrete side walls with hard brick arch, where ground is any way soft or unable to stand without wood lining while permanent lining is being laid. But with reasonably solid material overhead I would line completely with concrete. In two tunnels on this line we would need to introduce steel ribs to hold material while concrete is being placed, owing to swelling and running ground.

No formulas have been adopted for calculating thickness of concrete lining. A large factor of safety should be used, as the material (when lining is put in) may develop weaknesses which cannot be foreseen. An uneven weight is much more destructive to any lining than much heavier weight evenly distributed, and it is very difficult to make set rules for determining how much weight it will have to carry.

PENNSYLVANIA LINES.—Stone lining as high up as it can be conveniently set with a derrick car, brick for the balance. For swelling material the arch should have an invert. We have used no formulas. Our practice has been to use five rings of brick for single track, and six rings for double track, and these have proved ample. I do not know of any formulas applicable, as any assumptions as to loading must of necessity be vague and uncertain.

For protection against water seeping through the arch, the extrados was to be covered with cement plaster and pitch. This, and all other protective coatings, roofing-felt, asphalt, etc., placed outside the arch have proved ineffective, because the placing of the packing has invariably punctured and broken the protective coatings. In the last two tunnels built under my charge, I placed a layer of prepared roofing in the mortar joint next to the last ring. This has proved more effective than any other device.

PENNSYLVANIA RY.—We prefer stone or brick lining. The tunnel in which we have used concrete lining has not proved satisfactory. The majority of our tunnels are lined with brick rings and stone bench walls. In the latest tunnel we built we used sandstone rubble masonry for the lining throughout, and this has been very satisfactory.

We do not use any formula for determining the thickness of masonry lining. This is altogether covered by precedent and good practice.

ERIE RY.—Concrete side walls with brick arch; except in unsound material, when concrete with a flush surface of brick is preferable.

CAROLINA, CLINCHFIELD & OHIO RY.—We use concrete for tunnel lining, irrespective of the character of material through which the tunnel penetrates. The particular advantage of concrete is that for material which swells on exposure the introduction of reinforcing steel is feasible.

The use of brick, stone or concrete for lining tunnels will depend largely upon local conditions, such as availability of material and cost in that locality. Speaking purely from the standpoint of the structural value of these three materials commonly used for tunnel lining, there is no practical difference. If brick be specified, the quality of this material must be subject to careful inspection to insure proper texture and state of vitrifaction. Such brick should be hard-burned and capable of absorbing not more than 16 or 17% of water.

In the case of our tunnels lying along the valley of the Clinch River, the geological formation is such that the strata slope in a direction downward at 45° to the horizontal plane and to the east. At the Townes tunnel the disintegration of the strata has softened the material to such an extent that an unusual lateral pressure is brought upon the west wall, and for this case bent I-beams have been specified. This form of reinforcement is unique only in that the two vertical portions of the curved beams are of unequal length. The long side, of course, is situated on the west side of the tunnel to resist the lateral stress mentioned. These reinforcing ribs are placed from 2 ft. to 5 ft. apart, according to the thrust to be resisted. The amount of this thrust in each case was arrived at by noting the deflection of the double lining timbers at that point. It has been necessary to slope the bench walls of the tunnel to accommodate the contour of the long legs of the I-beams.

We do not use formulas for determining the thickness of masonry linings. For ordinary material it is assumed that the mass to be supported will be contained within the usual 45° planes. In special cases where the material is unusually loose, this mass to be supported is increased according to the judgment of the engineer.

BALTIMORE & OHIO RY.—Stone or brick side walls, with hard shale brick for the arch. The thickness of side walls is determined by the character of material through which tunnel is made. For thickness of arch, four rings (17½ ins.) for single track, and five rings (22 ins.) for double track was determined by same formulas as for ordinary arches. If material over arch is soft and wet, thickness of concrete haunching over brick ring to be increased, or increase thickness by one extra ring of bricks. This same precaution to be taken in case of falls; two extra rings (six in all) for each heavy fall encountered.

NORFOLK & WESTERN RY.—Where readily procurable, in all cases stone or concrete walls with brick arch. In some cases reinforced-concrete arch. We use

formulas for thickness, but rather observation of successful linings.

SOUTHERN PACIFIC RY.—Other things being equal, we prefer concrete invert, concrete side walls and brick arch, if the price of brick and other matters affecting cost are such as to make it of about the same price as concrete arch. If price of brick arch would be too great, we use concrete throughout. We do not favor rubble or coarse masonry lining.

NEW YORK CENTRAL RY.—Concrete lining preferred. We recommend lining all tunnels, as it will eliminate slickensiders.

CHICAGO, MILWAUKEE & ST. PAUL RY.—Concrete has been used in lining some 12 or 13 tunnels; not only in the side walls, but in the arch also. In a number of cases the timber lining did not give the full cross-section of tunnel intended, due to the inability to put it into place or subsequent movement, and the concrete sections would be less than indicated on the plans. The timbered tunnels were made with the view of being lined subsequently. Generally, the timbering was put in at intervals of 4-ft. centers; however, there were many cases in which it was necessary to put it in closer, and in such cases the timbering was solid. Generally, no attempt was made to remove the timbering unless it materially encroached on the concrete sections, so as to make it desirable to remove some of the timbers in order to obtain an adequate section of concrete.

DELAWARE, LACKAWANNA & WESTERN RY.—In the Kings Island tunnel, inspection disclosed pit marks throughout over the area affected by the blast of the engines. We are of the opinion that this was due to the concrete facing becoming dried out before it had thoroughly set, and that the remedy is a sufficiently wet mixture to retain sufficient moisture until the cement and concrete have thoroughly set. If the brick used in the lining of the roof were of proper character, vitrified throughout, such that they would not disintegrate from the effects of the gas or frost or blast of locomotives, the brick lining would be equally as good as the concrete. But on the score of economy and the elimination of the handling of the cars for the lining, the concrete lining for the roof was used in the Bergen tunnel.

Formulas of thickness are not used. Thickness is determined by practical construction in placing concrete, and depends to some extent upon the amount of overbreakage outside of the regular tunnel section.

NORTHERN PACIFIC RY.—The Bozeman tunnel (3,650 ft.) is approached on a 2% grade, and while the grade is lighter in the tunnel, it receives the effects of the engine due to the 2% grade. This tunnel was lined in 1895-6, approximately 300 ft. of the roof being lined with brick and the remainder with concrete. The walls are constructed of concrete throughout. Proportions of concrete are 1, 3 and 5, and English Portland cement was used. In the 300 ft. of brick lining probably 50 brick have been disintegrated and removed entirely, probably due to joint action of frost, gas and blast of engines. The concrete lining in this tunnel as a whole was in good repair. At the ends of the sections the roof was found disintegrated from ½ to 2 ins. or more in several places; also several places where the concrete had become removed, from the size of a chestnut to as large as a man's fist. In one place, where they had trouble with water during the work, the roof had sloughed off 3 to 6 ins. for a length of 20 ft. The remaining portion of the concrete was as good as when put in, and the defective roof in the concrete portion was due probably to the concrete not being properly mixed, not being wet enough, or that forms were removed too soon and allowed the blast to affect it. Possibly the result was a joint action of the blast and improper mixing of the concrete.

The Mullan tunnel (3,900 ft.), on a 2% grade, was lined in 1892-3-4. The walls are of concrete and the roof is lined with brick with the exception of the portals, which are lined with concrete. Proportions of concrete are 1, 3 and 5, and English Portland cement was used. The portals are in first-class condition and show no effects of weather, frost, gas or blast of locomotives. The brick lining has disintegrated. The bricks were not vitrified bricks, and the disintegration was due to frost action as much as to the effects of blast or gases of locomotives.

In the brick lining of both tunnels the concrete mortar used in brick shows no disintegration. This is an evidence that cement mortar resists frost, blast of locomotives and gases, and that the concrete if properly mixed and placed will give the same results.

Drainage in Tunnels.

LOUISVILLE & NASHVILLE RY.—We have one double-track tunnel where the drainage is carried through a concrete conduit down the center of the tunnel. No precautions are taken to prevent this conduit from filling. This drainage is believed to be efficient. Open side ditches are frequently unsatisfactory on account of the limited width of tunnel section giving but meager width for the ditches. We have not taken precautions to make such ditches smooth with concrete to facilitate shoveling out the accumulation in the ditch, with the single exception of the conduit in the double track tunnel above referred to. My preference for single-track tunnel is to have two ditches, one adjoining each wall of the tunnel.

NASHVILLE, CHATTANOOGA & ST. LOUIS RY.—In one tunnel, 2,200 ft. long, the drainage is carried along side ditches. In others, the width of the bottom not admitting of side ditches, drainage is secured by leaving openings through the center of the ties. We tried cast-iron pipe in the center, but the joints filled up and the pipes clogged. We also tried wooden boxes with the same result. Where water carries lime or other mineral which deposits in solution, do not think conduits would prove successful.

Our experience is that open side ditches give best drainage, but it is necessary to remove locomotive sparks from them frequently. Making them smooth with concrete to facilitate flushing would be advantageous. If the fall of the tunnel and the water supply is sufficient to take advantage of this in carrying out the accumulations, it might be well to concentrate the drainage in one ditch. This should be on the side, and not in the center. It would rarely be possible that the water could be made to carry off the accumulations. Under most conditions, therefore, I think two side ditches preferable.

PENNSYLVANIA LINES.—We use sewer pipe with uncemented joints, and have had no trouble from filling. The tunnel sections heretofore in use have not afforded sufficient room for adequate side ditches, but with wider sections side ditches would become effective, and render a central drain pipe unnecessary. We have not concreted our ditches, but I can conceive of cases where it might be desirable. It should not be recommended for general practice, but be left as a resort in special cases.

In single-track tunnel, I would provide for drainage at both sides, either by open ditch or pipe, as the individual case seemed to call for.

PENNSYLVANIA RY.—The only tunnel in which we have used conduits or pipes for carrying the drainage is a short one, and in this case we used tile drains on either side of the track, some 2 or 3 ft. below sub-grade. We covered these drains with broken stone. This has been very effective in draining the tunnel, which was built through very wet ground.

We have found open side ditches to be very effective for drainage, if of sufficient cross-section and kept properly cleaned out. We would prefer to drain a single-track tunnel by means of two ditches, one on either side of the track, as greater cross-section for the ditches could probably be secured thereby.

CAROLINA, CLINCHFIELD & OHIO RY.—We have one tunnel on a grade of 0.2%, 1,100 ft. in length, where the drainage is carried through an 8-in. vitrified terra-cotta pipe, laid in the center of the track. The bottom of the pipe is 2 ft. below sub-grade and the trench is filled with broken stone of ordinary ballast size. Prior to the laying of this drainage pipe the tunnel was very wet, the bottom strata through which the tunnel passed consisting of soft shale. Since the pipe line was laid the tunnel has been dry. We consider this method of drainage under these circumstances a good one. In 34 tunnels, aggregating nearly six miles in length, the drainage is taken care of in two open side ditches. Such ditches provide ample drainage if the grade is sufficient.

DELAWARE, LACKAWANNA & WESTERN RY.—Vitrified tile pipe laid with joints slightly open in ditch near outside edge of tunnel. Pipes covered over with broken stone. In our new Bergen tunnel (Jersey City) we have concreted the entire bottom (Bush track construction).* Would prefer to have drainage in a single-track tunnel distributed in two ditches.

BALTIMORE & OHIO RY.—For light drainage, one line of tile on each side of single track, with additional line in middle for double track; size of tile depending on local conditions. Efficient drainage in open ditches depends upon volume of water and gradient. For great volume of drainage, necessitating frequent cleaning of ditches, it has been found excellent practice to introduce open concrete ditches. This has been found to give good results in tunnels that have been in service for years.

According to wetness of tunnel 8-in. or 10-in. butt-end tile drains will make a satisfactory drainage, but cannot be absolutely depended upon. Both single and double-track tunnels should have two lines of drainage between track and side walls.

NEW YORK, NEW HAVEN & HARTFORD RY.—Pipe is located on center line of tunnel floor. Manholes are placed at points where direction changes, screens are placed at inlet basins, and outlet from manhole has a turn-down elbow with a screen. The flow of water is small and drainage is efficient.

No special precaution is taken to smooth up bottom, but stone ballast is used. Consider this important. Would favor two side ditches or a single center pipe.

SOUTHERN PACIFIC RY.—Clear water drainage is handled in the center of the tunnel underneath the ballast in horseshoe tiling; lowest part of invert being in the center of the tunnel. Muddy water drainage, if supposed to be permanently muddy, is handled in side ditches, the highest part of the invert being in the center of the tunnel.

*Engineering News, Aug. 19, 1909.

The Effect of Sewage and Sewage Gases on Concrete.

Ever since Portland cement was invented it has been used continually in the construction of sewers and in all kinds of plants in which sewage is treated or retained, where both the putrefying material and the gases generated have come in contact with the concrete. That such practice has become almost universal is prima facie evidence of the desirability of concrete in sewer construction, but, nevertheless, in a nearly negligible minority of instances there have been evidences of a partial disintegration of the surface of the concrete, and these cases have been widely used by certain interests to advertise the necessity of using some other material for any structure with which sewage comes in contact. These reported cases of disintegration have been very rare and not at all well authenticated so that when one which is vouched for by a competent engineer is available it is only right that it should be brought to the attention of the profession.

Such a case has recently been made public in a paper by Mr. Sidney H. Chambers, Engineer and Surveyor to the Hampton (England) Urban District Council, read before the Concrete Institute in London. This paper, bearing the title at the head of the present article, we reproduce below.

The subject of the present communication is one in regard to which it might be assumed that the available evidence is either inconclusive or of a more or less negative character. For, notwithstanding that cases are on record of destructive changes in tanks and sewers, the opinion tends to prevail that when concrete construction is sound no marked disintegration need be anticipated, either from sewage or from its emanations.

The author's experience, however, does not support this view, and it is to the elaboration of this, the positive side of the question, that he desires to direct attention. During the last five or six years he has had very special opportunities for studying the problem.

In order to be in a position to more fully appreciate the disintegratory changes occurring at Hampton, and the deductions drawn from them, it is necessary to describe, even though briefly, the installation in question, and to state the character of the sewage, as well as to outline the nature of the materials used in the construction of the tank and channels.

The Hampton Sewerage System.

The nature of the sewerage system is water carriage, primarily flowing by gravitation, and, secondly, raised by plenum pneumatic power. The sewerage is entirely and completely on the separate system. The installation consists of a screening chamber, two detritus tanks, a hydrolytic tank, and triple contact beds, and an air purifying filter.

The sewage on its arrival at the works is delivered from the rising main into the screening chamber, and, after passing through the screen, is conveyed by a channel to the detritus tanks. From these tanks the sewage enters the hydrolytic tank, which, together with the detritus tank, was installed in 1903. The disposition of the tank is such that the main bulk of the sewage—80%—passes through at a comparatively high rate of flow, issuing in four hours as a clarified liquid, while the small volume—20%—containing the deposited matters, is sixteen hours in the tank. After flowing over the weirs of the first portion the liquid enters a channel which leads to the second portion of the tank, consisting of four hydrolysing chambers arranged in sequence, and filled with large flint stones. The liquid having taken three hours in its passage through these four chambers, enters the lower channel, which conducts it to the contact beds.

The screening chamber, the tank, and the channels leading to and from the tank, as also the effluent channel of the primary contact beds, are covered in. The entire installation is ventilated by the hydro-mechanical system of sewer ventilation, and the withdrawn gases are purified by being passed through an air filter.

The sewage of Hampton is of a strong domestic character. It has undergone thorough disintegration by the lifting operations and by the putrefactive changes occurring in the rising main. It is malodorous on its arrival at the screening chamber, where, as it leaves the rising main, it evolves sulphuretted hydrogen and other bad smelling compounds. The liberation of these gases constitutes a nuisance necessitating the screening chamber, channels, and tank being covered in, and a means being provided for drawing a large volume of air through them before discharging the gases into the atmosphere.

CHARACTER OF CONCRETE.—The whole of the tank and channels are constructed of Portland cement concrete. The walls of the tank are 6 ft. 6 ins. in thickness at the base, and 1 ft. 6 ins. at the top, and are strengthened by tie-rods; the roof is 6 ins. in depth and is reinforced by

expanded metal, and the channels are covered by 2-in. "Indurated" paving slabs. The work was executed by departmental labor, and the best materials were used.

The concrete was composed of one part of Portland cement properly mixed with clean water and six parts of ballast thoroughly free from loam, clay, mud, or dirt of any kind, and no material was allowed to be larger than would pass through a 2-in. screen.

The makers of the "Indurated" paving flags state that they are composed of Mountsorrel granite chippings, washed and crushed to pass through a ¼-in. mesh sieve, and heavy Portland cement made by themselves, the raw material for which is obtained from the Barrow-on-Soar Blue Lias beds. The materials are mixed in the proportion of one part of cement to three parts of granite.

Effect of Sewage.

EFFLORESCENCE.—Early in 1905, a few months after the hydrolytic tank had been put into use, it was noticed that the roof and walls of the hydrolysing chambers above the liquid level were white or yellowish in appearance. This efflorescence was not crystalline in structure, but was of a chalky subsistence, and resembled distempered work on a damp wall. On examination it was found to be due to a thin covering of sulphur, which could be easily removed by rubbing. Later the face of the walls and the roof in the second part of the tank showed signs of peeling, and the concrete appeared to be disintegrating. A thorough inspection of the installation was thereupon made.

DISINTEGRATION.—At the screening chamber nothing appreciable was observed, neither at the highest water-level nor on the underside of the roof. The concrete was sound, and when struck had a good ring. Immediately adjoining this chamber was the main sewage inlet channel, along which the whole of the gases pass to the main air duct leading to the air filter. At this point slots were made in the concrete to receive a dam; the concrete at the back of the grooves was found to have disintegrated, although the sides were perfectly sound.

Farther along this channel it was observed that the greatest disintegration had taken place on the walls at the liquid level. Owing to variations in the flow of the sewage, the level of the liquid in the tank and channels rose and fell; thus a certain area of the walls was constantly being immersed in the sewage and then exposed to the air. This area was, consequently, even when not immersed, much wetter than the part of the walls which was always above the level of the liquid. The latter area at this point showed erosion, which, however, had not penetrated so deeply that at the level of the liquid itself. At the liquid level there was a deep groove in the concrete, and above this the face of the work had bulged out and lost its nature.

The first portion of the tank, i. e., the hydrolytic tank proper, appears to have suffered very little. The walls and roof have only the slight sulphur deposit. At the liquid level, which varies less than in the channel, there is a slight erosion. The second part of the tank, i. e., the hydrolysing chambers, was found to have suffered in places to a marked degree. It was observed on breaking through the erosion on the surface that the concrete at the back was moist, soft and gritty. Also, it was noticed that increased dampness constituted an important factor in the destruction of the concrete, for the lower parts of the vertical faces of the beams supporting the roof were more affected than the upper parts. The lower portions of the vertical walls of the tank also are more eroded than the upper. At the liquid level the concrete has been severely attacked, and a deep groove exists in it.

ANALYSES OF CONCRETE IN HYDROLYTIC TANK.—Two samples of surface concrete were taken above and below the liquid level, and the following is the result of the analyses:

	Below liquid level. Sound.	Above liquid level. Unsound.
Appearance	Grey	White
Texture	Hard	Soft
Ratio cement to sand	1 : 2	3 : 2
Sulphate of lime in cement	Trace	66%

The same pronounced effect is to be seen in connection with the concrete blocks, which were grooved to receive sliding boards and project above the liquid level; these blocks in many instances have crumbled away to such an extent as to be almost shapeless. Recently these chambers were emptied, and it was found that the concrete below the liquid level was perfectly sound and in a good state of preservation.

The lower channel conveying the liquid from the tank to the contact beds revealed the same characteristics as were observed in the upper channel, but the portion at the liquid level was very much more markedly affected.

ANALYSES OF THE DISINTEGRATED CONCRETE IN THE CHANNELS.—Samples taken of the lining of the sides and covering gave the following analyses:

	Ratio—Cement.	Ratio—Sand.	Sulphate of lime in cement
1. Concrete at varying liquid level	1	1	70.26
2. Underside of slab forming covering..	5	1	74.61

The air duct taking the gases from the effluent channel of the primary beds and communicating with the tank outlet channel was found to have a coating similar in appearance to that observed on the underside of the covering to the channels.

ANALYSES OF CONCRETE IN AIR DUCT.—Analyses of this coating were made, with the following results:

	Ratio—Cement.	Ratio—Sand.	Sulphate of lime in cement
Underside of slab forming covering of air duct.....	2	1	70.71

The point to observe in the above analyses is the conversion of the lime in the cement into sulphate of lime, the sulphur being obtained from the sewage flowing through the tank and channels, as well as from the gases expelled from the sewage, and contained in the air withdrawn from the several parts of the installation.

Suggested Explanation.

Much thought has been given to the explanation of the foregoing observations, and it has been concluded that the effects have arisen from the putridity of the sewage and the oxidation of the putrid products by the air supply. The main erosive effect was at the varying liquid level, and was there dependent upon the amount of sulphuretted hydrogen in solution in the liquid. The gas was comparatively small in amount in the incoming sewage and in the liquid in the hydrolytic tank, and increased as the liquid passed through the hydrolysing chambers. The results of this are especially well shown in the two channels; the alternate wet and dry area of the upper channel conveying the sewage from the rising main was less markedly affected, while in the lower channel the corresponding area was severely attacked. So with the two parts of the tank; the first part into which the sewage was delivered, and wherein comparatively little putrefaction took place, has not been affected to anything like the extent that the second part or hydrolysing chambers have.

When the level of the liquid fell it left the concrete which it previously covered wetted with a liquid containing sulphuretted hydrogen in solution. This wet surface was then exposed to the action of the air supply, which oxidized the sulphuretted hydrogen with the production of sulphur and sulphuric acids; these decomposed the concrete, the lime being converted finally into sulphate of lime. What the exact nature of the intermediate compounds was cannot be stated, as none of them have been isolated, but it is probable that the active agent was sulphurous acid, as it is known that cement is insoluble in sulphuric acid. When the liquid rose again, the decomposed concrete was washed away either wholly or in part, and a fresh surface was exposed to action when the liquid fell again. It was the continuation of this cycle which led to the formation of the grooves at the varying liquid level.

The erosive effects on the concrete above the liquid level are dependent upon the sulphuretted hydrogen evolved from the liquid and mixed with the air supply. Some of this gas is dissolved by the moisture which is present on the walls and roofs, from evaporation and condensation; it is then oxidized by the air, and decomposed the concrete as described above. In this case the decomposed concrete either remained as a coating on the surface, peeled off, or crumbled away.

Tests on Concrete Tubes.

In order to observe the phenomenon on concrete tubes, two 9-in. concrete tubes were selected, which were supplied by the makers of the paving slabs previously referred to, and were composed also of similar materials in the same proportion. One of the tubes was coated with a composition of coal-tar, pitch, linseed oil and resin. They were placed side by side in the second part of the tank in such a position that they would be subjected to the rise and fall in the level of the liquid. At low level the tubes were not in contact with the liquid, and at high level the liquid rose to half the diameter.

After the tubes had remained in the tank for eight months they were taken out and examined. The coated tube did not appear to have been affected, other than at the highest liquid level, where a thin line could be observed, and when struck it was found hard and had a good sound. It was noticed that there were two areas on this tube without any coating, due no doubt to its having been placed upon two supports to allow it to dry; these areas were soft on the surface and similar to the uncoated tube. With these exceptions the tube appeared to be in as good a condition as when first placed in the tank. On the other hand, the uncoated tube had a distinct line at the highest liquid level, which was found to be soft, and when tapped with a chisel had a dull sound; the interior of the tube which had been immersed appeared soft and had a dull sound when struck; the portion of the tube above the liquid level was unaffected, and when struck had a clear ring.

Conclusions.

The deductions to be drawn from the investigations are that the gases in solution in sewage, and those expelled from it, arising from its decomposition, do act injuriously upon Portland cement concrete, notwithstanding the fact that the concrete is constituted of sound and good materials, when the following conditions prevail:

1. A high degree of putrescence of the sewage.
2. A moistened surface, which holds or absorbs the putrid gases.
3. The presence of a free air supply.

Further, in the absence of one or other of the above enumerated factors, little danger from erosion need be feared.

In the discussion that followed the presentation of the paper, there were one or two accounts of similar disintegrations in tropical countries, where the sewage reaches a high intensity of decomposition and where also the humid and hot climate would favor the destructive action of sewage on concrete, but by far the greater number of engineers reporting on the matter, said that, in their experience, good concrete had never been affected by sewage.

The New Sewage Experiment Station of the Massachusetts Institute of Technology.

By C.-E. A. WINSLOW,* and EARLE B. PHELPS,† Assoc. Am. Soc. C. E.

The Sanitary Research Laboratory and Sewage Experiment Station of the Massachusetts Institute of Technology was established in 1902 by an anonymous donor

for the purpose of making experiments on sewage purification and of giving the widest possible publicity to means or methods by which the present too often crude and imperfect systems may be improved.

Small experimental tanks and filters were installed in an experiment station at Albany St., Boston, in 1903. The results of the first two years' work, with a History of the Sewage Disposal Problem, were published in 1906, by the U. S. Geological Survey as Water-Supply and Irrigation Paper No. 185. In 1905 a new outdoor trickling filter was built (Eng. News, May 16, 1906) and the results of two years more of work, with a number of special papers on sewage disinfection and other problems, were published in 1907 and 1908. A third two-year set of experiments was completed in 1909, and, the same generous donor supporting the work, it was determined at that time to move to a new location and erect a more extensive experimental plant.

Two main objects were in view. In the first place a larger installation was desired than could be constructed at Albany St. In the second place it was considered important to secure a gravity flow, since the drawing of sewage from a street sewer by a small pump necessarily entails more or less straining and comminution of the larger suspended solids. This may appreciably affect the results, particularly in regard to the clogging of filters to which crude sewage is applied.

The new experimental plant, which has been in operation since July, 1909, is at Old Harbor Point in Dorchester, on land adjoining the pumping station of the Boston Main Drainage Works. The experiments are conducted here by courtesy of Mr. Guy C. Emerson, M. Am. Soc. C. E., Superintendent of Streets, and the work has been and is greatly facilitated by the kindness of Mr. C. B. Pratt, Deputy Superintendent, and Mr. E. S. Dorr, M. Am. Soc. C. E., Chief Engineer of the Sewer Department

At the Old Harbor Point (or Calf Pasture) pumping station the sewage of the Boston Main Drainage District, amounting on an average to about 85,000,000 gals. a day, is screened through bar screens having 1-in. openings and then pumped from about 7 ft. below to 29.6 ft. above mean low water (El. 0). The sewage flows over two weirs, each 8 ft. long, with crests at Elev. 26.5 into two long deposit sewers, leading to the entrance shaft of the tunnel under Dorchester Bay. The deposit sewers are designed to settle out the coarser solids so as to protect the tunnel.

Sewage for the Technology station is drawn from the pipe chamber, just above the weirs, through a 4-in. wrought-iron pipe with invert at Elev. 25.25. In order to insert this pipe it was necessary to drill through 4 ft. of granite wall

*Biologist-in-Charge, Sanitary Research Laboratory and Sewage Experiment Station, Massachusetts Institute of Technology.
†Sanitary Research Laboratory and Sewage Experiment Station, Massachusetts Institute of Technology.

The sewage thus obtained is ideal, representing practically the whole of the city of Boston, well mixed by the pump, and containing all the suspended solids which pass a 1-in. screen.

The sewage drawn off by the 4-in. pipe is first subjected to grit-chamber treatment, comparable to that which the main body of sewage receives in the deposit sewers. Two duplicate grit chambers are provided, each being a 4 × 4 × 4-ft. wooden box, and the sewage passes through one of the pair. The height of sewage in the grit chamber is automatically controlled by a float and by a butterfly valve on the inlet pipe.

The sewage flows from the grit chamber through a 4-in. vitrified pipe laid in the side of the deposit-sewer embankment for a distance of 235 ft., at a grade of 0.33%. At the end of this line is a brick manhole, from which the line turns and is carried across a roadway, the pipe being enclosed in a square wooden box-trough over a 15-ft. main space and two 5-ft. approaches.

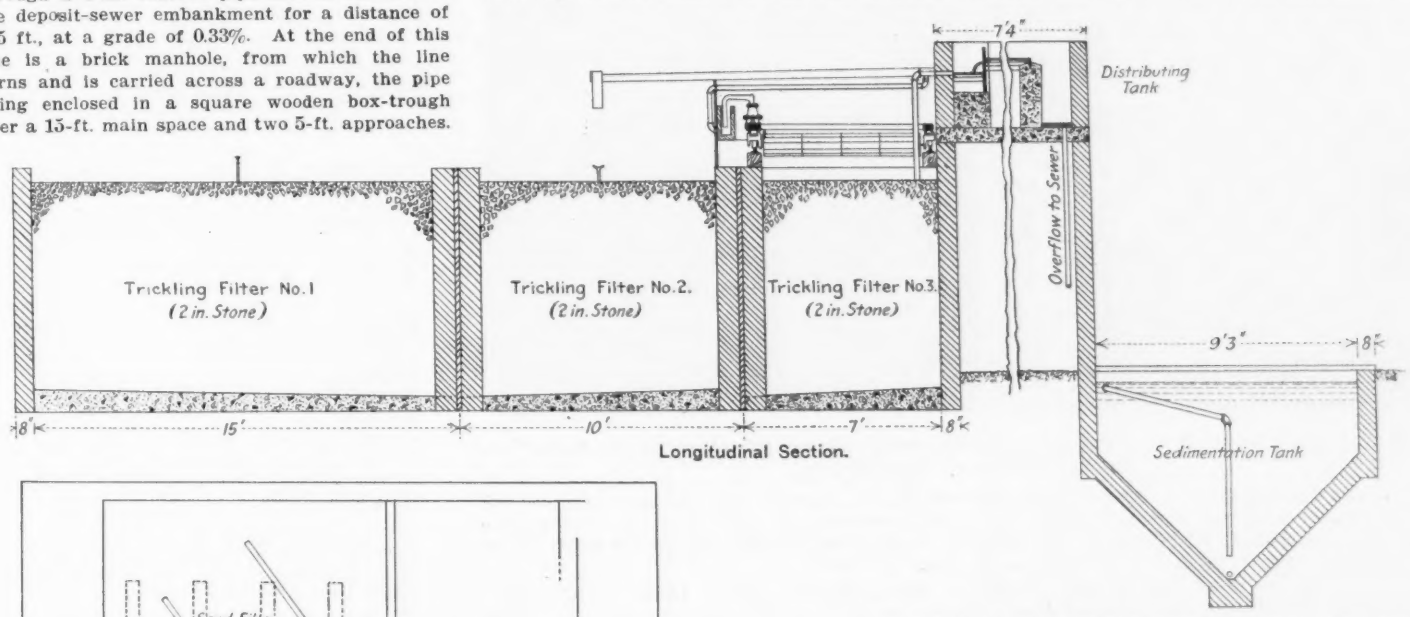


FIG. 1. PLAN AND SECTION OF THE NEW SEWAGE EXPERIMENT STATION OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, BOSTON, MASS.

Part of this overhead structure is shown in Fig. 3.

The plant itself includes eight main elements: a distributing tank, three trickling [percolating] filters, a septic tank, a sand filter, a sedimentation tank for effluents and a Dibdin slate bed. All were constructed on the foundations and within the walls of a ruined building which was once the ammonia recovery building of a garbage-reduction plant. Figs. 1 and 2 show a plan and a section of the plant and Fig. 3 is a general view taken from the top of the deposit-sewer embankment.

The distributing tank is of concrete, 6 × 4 ft. in plan and 5 ft. deep to the flow line. At 1 ft. from one end is a concrete wall topped with a weir, over which an excess of sewage flows off to the drain, and at the other end four cast-iron plates separate four small chambers from the main tank. These plates are slotted and each carries a brass orifice plate, which is adjustable vertically. In this way the rates are properly regulated. From each of these small chambers the sewage passes freely to the filter or tank as the case may be.

TRICKLING FILTERS.—The trickling filters are all alike in general construction, the distributing device, only, differing in each case. The floor of the filters is of concrete, sloped toward the outlets, and 4-in. half-round tile underdrains were laid on the floor to further facilitate drainage. The outer walls are of brick, and the partitions between the beds of 2-in. planking. The filters are composed of 7.5 ft. of 2-in. crushed stone, granite and trap.

Filter No. 1 is 15 ft. sq. and is dosed by a Taylor nozzle designed to cover a square. The device must be operated under a head, which varies at such a rate that as the sheet moves in and out, the discharges on unit areas shall be approximately equal. In this case the head is varied by the revolution of a disk with properly-designed openings, placed over the orifice plate already mentioned. The disk is automatically revolved by a clock and electromagnet device in the adjacent laboratory.

Filter No. 2 is 10 ft. sq. and is dosed by a gravity distributor of the type devised at the Albany St. Station. Sewage is carried out over the filter in a wooden trough, from the bottom of which a stream discharges downward and splashes out from a concave disk supported on a standard on the surface of the bed.

Filter No. 3 is a 7 × 15-ft. rectangle, and is dosed by a Fiddian traveling distributor built for the station by Ham, Baker & Co., of London. This distributor represents one of the best types of English moving distributors (Fig. 4).

All three trickling filters are of the same depth and contain the same filling material, all receive crude sewage, and all are operated at the same rate, approximately 2,500,000 gals. per acre per day. The variable factor lies only in the method of distribution, No. 3 being dosed with almost theoretical evenness, No. 1 receiving the best distribution possible with a fixed nozzle, and No. 2 getting only such a distribution as is possible without mechanical devices or varying head.

SEPTIC OR BIOLYTIC TANK.—The sewage from the fourth regulator chamber passes to the septic tank and thence to the intermittent sand filter. The septic tank shown in Fig. 5 is somewhat novel in design. It is like the Dortmund tanks used for plain sedimentation. We have become convinced from a consideration of experience at other plants and from some small-scale experiments carried out in the Institute laboratories by Mr. J. H. White that the main factor which limits the liquefaction of sludge is an over-septic condition, accompanied by the production of toxic bacterial products. If this be the case the principle of the Hampton and Ems tanks, in which the sludge is separated from the sewage flow and subjected to intensive septic action, is an erroneous one. We have attempted to secure precisely the opposite result, by washing the sludge constantly in a current of fresh sewage and thus removing the products of bacterial decomposition. As the essential principle of the septic tank is recognized to be the retention of the sewage so as to promote anaerobic conditions as far as possible, while our aim is to limit these conditions, this tank is hardly a septic tank at all in the ordinary use of the term and might better be called a biolytic tank.

The tank itself is square at the top, and 7 ft. across. The straight sides extend downward for 2.5 ft., below which the walls converge to form a hopper. They have a slope of about 55 degrees with the horizontal. The capacity is 1,540 gals., and the flow period 8.5 hrs. The sewage enters through a 2-in. pipe about 9 ins. from the bottom and the effluent is skimmed off at the surface by four 60-degree triangular metal weirs, placed at the corners and discharging into 2-in. channels in the walls. Scum-boards protect these weirs. At the bottom of the tank is a 2-in. effluent drain for sludge.

The septic effluent passes to a wooden dosing tank with a capacity of 850 gals., which discharges by an automatic siphon onto the sand filter. The daily flow through the septic tank is 4,250 gals., so that the dosing tank discharges about once in five hours.

SAND FILTER.—The sand filter, shown in Figs. 1 and 3, is 21 × 22 ft. in plan, or 462 sq. ft. in area, so that the dose of 4,250 gals. amounts to a rate of approximately 400,000 gals. per acre per day. The filter was built on

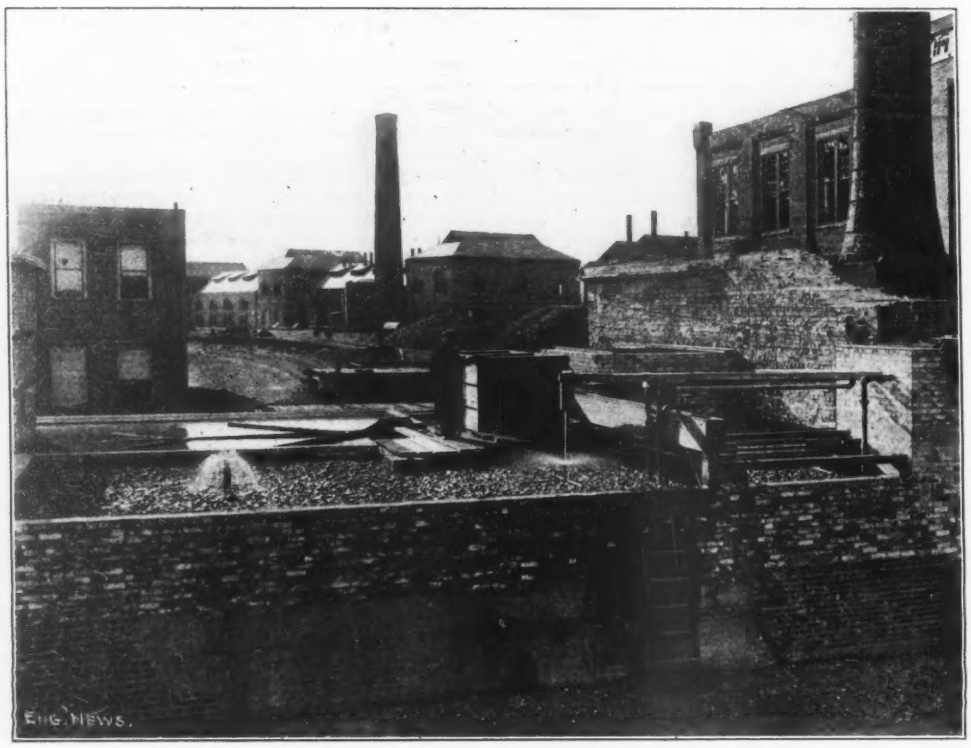


FIG. 2. GENERAL VIEW OF NEW SEWAGE EXPERIMENT STATION, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, BOSTON, MASS.

the old brick floor of the ruin. For underdrains 4-in. half-round tile pipes were laid in the four rectangular channels shown in Fig. 1. The sand layer is 3.5 ft. deep and consists of beach sand with an effective size of 0.36 mm. and a uniformity coefficient of 1.9. It was obtained from a beach in the immediate vicinity. The sewage is distributed on the bed by a system of wooden troughs, shown in Figs. 1 and 3, with 1-in. outlets 6 ins. apart, on the sides.

The effluents from the trickling filters and the sand filter pass to cement channels in an arched brick tunnel under the floor, which serves as a ventilating and sampling chamber. The sand-filter effluent is finally discharged into a drain which returns to the pumping station. The trickling effluents are mixed and pass either to the sedimentation tank or to the slate bed.

SEDIMENTATION TANKS.—The sedimentation tank is of the same general form as the septic tank, with such modifications in dimensions as were made necessary by the limited head available. As indicated in Fig. 2, the tank is below the surface of the ground. The upper part is 9¼ ft. sq., and the lower pyramidal sides have a slope of 40 degrees. The capacity is 2,200 gals., giving a storage period of 2.2 hrs., for the combined effluents of the three trickling filters. The inlet pipe dips into the sludge, as in the septic tank, and the effluent is skimmed off by triangular weirs at the corners. A 2-in. iron sludge pipe runs from the bottom to a pit in the waste manhole. The sludge is drawn off daily, so as to avoid septic action.

SLATE CONTACT BED.—A portion of the trickling effluent is diverted at intervals to the slate bed, which is a wooden tank 4 × 8 ft. in plan by 4 ft. deep filled with even layers of 6 × 10-in. slates, separated by cement blocks 1 in. thick, arranged on the plan of Dibdin's slate bed, and operated on the contact principle, with two fillings a day. The use of the slate bed as a secondary process for treating trickling effluent is, of course, merely an experiment, which will throw no light upon the question of the use of such a bed for the preliminary treatment of crude sewage.

GENERAL.—The detail plans for the plant were worked out by Messrs. A. B. Morrill and M. R. Scharff, under the direction of the writers. The work of construction was carried out by the Andrew D. Fuller Co. The cost of the principal items is tabulated below.

The plant is operated for 24 hours in the day, for six days in the week, during the greater part of the year and for seven days in freezing weather. Samples of sewage and of all effluents are taken once every three hours. They are mixed, chloroformed and analyzed weekly. Special samples are examined daily for stability by the methylene-blue test.

COST OF EXPERIMENTAL PLANT.

Labor	$1,539
Stone	285
Cement sewer pipe	123
Lumber	61
Iron work	46
Pipe and fittings	66
Siphon	25
Slates	9
Minor materials	43
Fiddian distributor	146
Express	12
Total	$2,355

The new laboratory and the office of the Sanitary Research Laboratory are located in the Pierce Building of the Massachusetts Institute of Technology, at 30 Trinity Place, Boston.

The main problems, upon which it is hoped that light may be thrown by the routine work of the station, may be summarized as follows: (1) the practicability of treating normal Boston sewage, under actual working conditions, on trickling beds of 2-in. stone, without preliminary treatment other than coarse screening and removal of heavy detritus; (2) the actual effect upon purifying efficiency of mechanical distributors, compared with simpler spraying and splashing devices; (3) the efficiency of a biolytic tank of the Dortmund pattern designed to keep the waste products washed out from the decomposing sludge; (4) the practicability of treating septic effluent on a sand filter operated at high rates under Massachusetts conditions; (5) the efficiency of the sedimentation of trickling-filter effluent in a tank of the Dortmund pattern; (6) the possibility of treating trickling effluent for removal of solids in a slate bed.

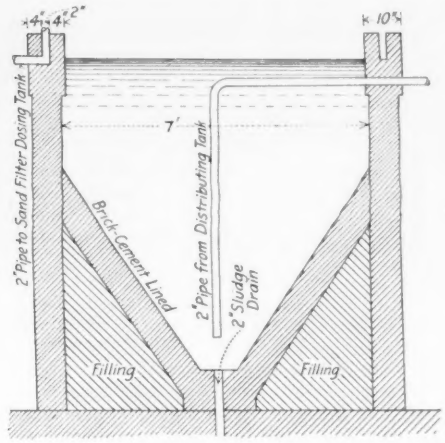


Fig. 4. Cross Section of Septic or Biolytic Tank, Sewage Experiment Station, Massachusetts Institute of Technology.

TELEPHONE AND TELEGRAPH COMPANIES IN New York State are to be brought under the Jurisdiction of the Public Service Commission of the Second District, in accordance with an act recently passed by the legislature.

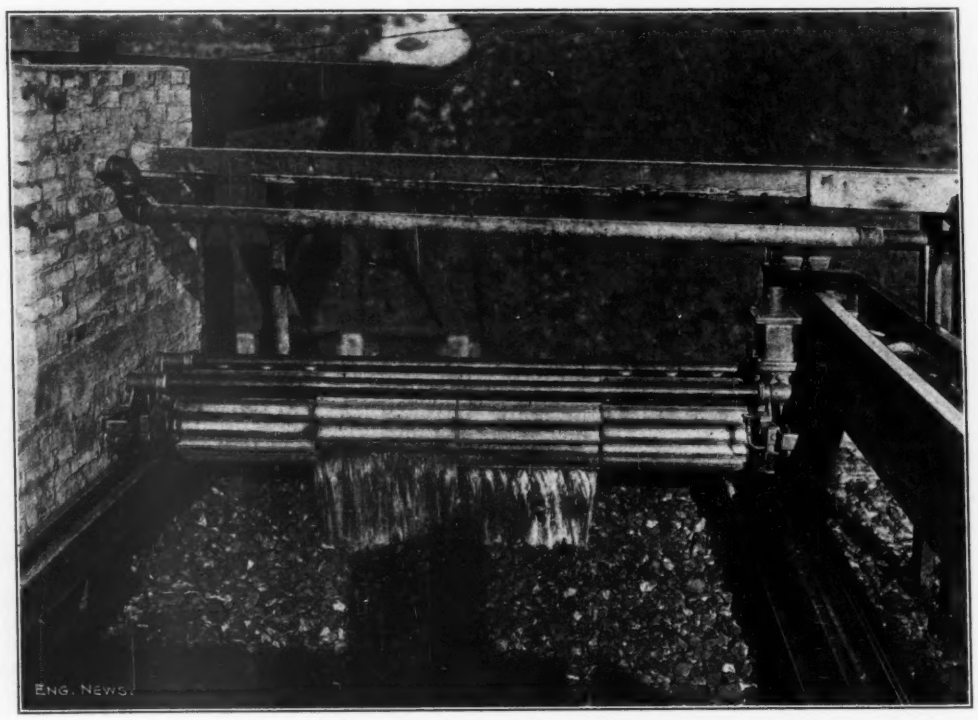


FIG. 3. VIEW OF FIDDIAN TRAVELLING SEWAGE DISTRIBUTOR, SEWAGE EXPERIMENT STATION, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, BOSTON, MASS.

Report on the Proposed Board of Water-Supply Pressure Tunnel Beneath New York City.*

In answer to the first question asked us, namely: "Is the proposed Manhattan tunnel practicable, from an engineering and geological standpoint," we may say as follows:

The proposed Manhattan tunnel is to be a "pressure tunnel," running from the proposed Hillview Reservoir, located at the down-stream end of the Catskill water-supply conduit now under construction and about half completed, thence passing under the westerly part and the middle of Manhattan Island, and thence across to Brooklyn. Its route has been thus selected so as to cause the tunnel to pass through a territory promising to be the best that can be found between the end points described. In carrying capacity it is gradually to diminish, from Hillview to Brooklyn.

A "pressure tunnel," which is thus designated on account of its being designed to convey water under pressure, must be placed, as usually constructed, at such a depth below the surface of the ground that the weight per sq. ft. of the overlying material is at least equal to the pressure per sq. ft. upwards of the contained water. Such a location, as regards depth below the surface, places no reliance on the strength, or resistance to rupture, of the surrounding ledge rock, and is therefore conservatively safe.

In the present instance, this method of construction places the tunnel about 200 ft. below the street level, but for the purposes of crossing in good rock, under the Harlem River, Manhattanville Valley, and the East River, this depth is increased to about 350 ft. and to not less than about 600 ft., respectively, and kept elsewhere at not less than 150 ft. beneath the "rock floor."

BORINGS.—To explore the nature of the ground, and when necessary to find lower down the good rock referred to, bore holes have been put down, since December, 1908, all along the line described. This line passes under streets, parks and other property of the city, some 18 miles, with the exception only of about a quarter of a mile of right-of-way to be acquired; 125 such bore holes have been completed, and at least 30 more have been begun (or are planned) extending in many cases to the proposed tunnel grade. This will give indications of the nature of the ground to be met with in tunneling, much more complete and instructive than formed the basis of the location of other pressure tunnels that have been built in years past. It should be remembered in this connection that the art of making borings and of extracting core specimens of rock penetrated is constantly advancing, no less than other arts. No such knowledge beforehand of conditions to be encountered as is now available was at hand, for instance, for the builders of the Harlem River crossing of the New Croton Aqueduct pressure tunnel, built 20 years ago. Nor for the construction of certain other such tunnels, built since that time.

AVAILABLE DATA.—We have carefully studied the geological data thus and otherwise made available, including the experiences had in other tunneling operations in this vicinity; such as the construction of the Harlem River Pressure Tunnel, built in 1885-1891, just mentioned; the Pennsylvania R. R. Tunnels, lately completed; the Webster Ave. sewer, running to the Harlem River; the Bronx Valley Storm Relief Sewer, now under construction; the Rondout, Wallkill and Moodna pressure tunnels, forming a part of the new Castkill Water Supply, two of them built at a level of 200 ft. below sea level, which we have personally examined; the Steinway Tunnel and the East River Gas Tunnel; the Battery Tunnel to Brooklyn, and certain shafts put down in Manhattan Borough.

We have gone over the whole length of the line described, from the East River to Hillview, and have examined the rock cores or specimens brought up in the making of the bore holes named, which are preserved for future use in the letting of the construction contracts, at the 92d St. Gate House. We have also studied, up to date, the weekly reports made concerning the bore holes now being put down.

GEOLOGICAL CONCLUSIONS.—From a detailed examination of all the geological data accessible we are of the opinion that the construction of a pressure tunnel along the line laid down on the plats of the Board of Water Supply, and its subsequent maintenance, are entirely practicable. Keeping in mind the geology of the district to be traversed, which we regard as unusually well explored, it seems unlikely that such seams, soft spots, loose pockets, faults or zones of crushing or of deep decay should be met, even for short distances, as will render impracticable the proper construction of the tunnel at the depths proposed; and it does not appear at this writing probable even that such conditions will be met as will require any material change from the present plans of the Board of Water Supply, with the possible exceptions noted below.

Concerning a short distance across the lower side of Manhattan from the corner of Spring St. and the Bowery to the river front at Clinton St., the geological data are still incomplete. From the conditions of the deep rock as shown by gross and microscopic examination of rock cores from this field, we are convinced that this section also is a practicable route substantially as proposed; but final judgment must be deferred upon the depth and character of the tunnel, the cost, and upon the time required for the construction of the shafts and tunnels in this section, pending the completion of the boring operations conducted by the Board of Water Supply. The same may be said concerning the line for a distance of about 1,000 ft. on 106th St. Detailed geological data upon which these deductions are based are discussed in Appendices A, B and C. [None of the appendices are reprinted here except the one given in the long foot note.—Ed.]

OTHER PRESSURE TUNNELS IN THE UNITED STATES.—Pressure tunnels, so far as we are informed, had their beginning in the United States right here in New York. The Harlem River crossing of the New Croton Aqueduct, 1885-1891, being the first pressure tunnel built, so far as we know; seven miles long, and containing a pressure of 103 ft. of water (about 45 lbs. per sq. in.)

The accomplished Chief Engineer of this work, the late Mr. A. Fteley (p. 87 of his report dated Jan. 1, 1895) says this concerning the Harlem River crossing tunnel: "This feature, that is, the construction of the aqueduct for seven miles, under pressure, is a bold innovation."

However the point of priority may be decided, true it is that the Harlem River pressure tunnel has been in every way a complete success for the twenty years of its existeuce in service, and others have not hesitated to profit by its example.

Thus there is a pressure tunnel under the City of Washington, put into service in 1898, after it had lain defective, unfinished and idle for a period of nigh ten years; four miles long, and carrying a pressure of 123 ft. of water (53 lbs. per sq. in.) 1,000 ft. of it, where it passes under Rock Creek, is lined with cast-iron rings. The Board of Engineers, which reported in 1896 recommending the completion of the tunnel, was divided in opinion, whether the safe transit of these 1,000 ft. under the Rock Creek Valley should be made by going deeper and into sound rock for that length, or by lining the tunnel, some 9 ft. in diameter, with cast-iron rings. The lining method was adopted, and there is no doubt that the other method would have given equally good results.

The history of both pressure tunnels and of conduits not under pressure built by tunneling methods (and much such history has been written in the United States in the past 25 years) plainly teaches what are the essentials of good design; and also the necessity on the part of the supervising engineer to see to it that the conditions of the specifications be carried out during construction. There can no longer be any doubt that good design as well as faithful performance of the specifications can now be secured.

Pressure tunnels carrying 60, 37 and 21 ft. of water pressure are in service in Cincinnati, Kansas City and Philadelphia, built between 1900 and 1906; and many others, built so as to run full of water, but carrying no unbalanced pressure, are in use in the United States. The Cincinnati tunnel is noted for having been constructed in the face of a greater than the usually found quantity of inflow of water; due to the seamy, soft yellow limestone of the Ohio Valley through which this tunnel passes.

An instructive example of the practicabilities of such structures, even when at first of defective design, is given by the pressure tunnel, in effect the penstock or pipe carrying the power water, to the Kern River hydro-electric plant of the Southern California Edison Co., of Los Angeles, Cal. Parts of this tunnel act under a pressure of about 870 ft. (about 380 lbs. per sq. in.), about double the pressure put on a modern high-pressure steam boiler.

This tunnel, as first completed in 1907, had no proper location or lining to resist either internal or external pressure. Nevertheless, by the skillful design and thorough work of the present vice-president and general manager, it has been restored to its intended usefulness, and has been in service since Sept. 1, 1909.

The many acres of ledge rock, honeycombed with tunnels which were placed with their roof within some 20 ft. of the bottom of the river, and used in the removal of obstructions to navigation at Hell Gate, in the East River, form another well-known illustration, in this vicinity, of practicable tunneling carried on in submerged rock, close to, and directly under the river.

OPINION.—An unusually complete collection of geological data, and the results of borings already made, thus make it highly probable that none but the ordinary difficulties of plain tunneling will be met with in the construction of the proposed Manhattan pressure tunnel; and the experience had in the construction of other pressure tunnels in this vicinity and elsewhere in the United States, during the past 25 years, change this probability into a certainty that the proposed pressure tunnel is practicable. Whatever bad ground may be revealed by the actual work of tunnel building, which the borings made and yet to be made have not revealed, can be passed through, over, under or around by methods that have been used in like cases elsewhere, and at no extraordinary cost.

We therefore answer in the affirmative your first question: "Is the proposed Manhattan tunnel practicable from an engineering and geological standpoint?"

COMPARATIVE PROJECTS.—Your second question is: "How does the estimated and probable first cost of this tunnel compare with (a) the estimated and probable first cost of a pipe line from Hillview Reservoir through Queens to the Borough of Manhattan, and (b) a pressure tunnel from Hillview through Queens to Brooklyn?"

The question is intended, we assume, to call for comparisons of cost on the routes and of the kinds of water conduits described, when built of equal water and pressure carrying capacity, and serving an equal area of distribution; as otherwise a comparison could not be made.

The proposed Manhattan pressure tunnel, like the Catskill aqueduct now building, is to carry, at its up-stream end, a supply of 500 m. g. d.; and passing, in gradually diminishing sizes, to Brooklyn through the Boroughs of the Bronx and Manhattan, will supply the distribution systems of these boroughs, at a pressure, where desired, of about 100 ft. (43 lbs. per sq. in.) greater than at present; and by pipe line extensions it will also thus supply the Boroughs of Queens and Richmond; that is, at pressures, where desired, of about 275 ft. in the Bronx; 280 ft. in Manhattan; 245 ft. in Queens, and 225 ft. in Richmond; while any conduit built on the line direct from Hillview through Queens to Brooklyn will necessarily demand other and additional conduits also to supply Manhattan Island.

INCREASED PRESSURE WHEN DESIRED.—We cannot assume that no portion of the Catskill Water Supply will at no time be needed in the Borough of Manhattan. We believe, on the contrary, that its delivery under the increased pressure, nearly 100 ft. (43 lbs. per sq. in.) of increased pressure, which the proposed Manhattan pressure tunnel would furnish, would be of very great value to the Borough of Manhattan to-day, and for all time, in giving, eventually, the chief city of the United States a pressure in its supply for fire and domestic purposes such as is customary in other cities and villages of the United States, and in relieving the city from a very great daily expense of pumping water those same 100 ft. at High-Service City Pumping Stations, and also at thousands of privately-owned pumping-engine plants of all kinds, located in dwellings and other buildings.

The Manhattan pressure tunnel is designed to deliver water at many uptake shafts, placed at intervals of

*Report by Messrs. Clemens Herschel, Hydraulic Engineer, Francis L. Pruyn, Consulting Engineer, and J. Edmund Woodman, Mining Geologist, to Messrs. Wm. A. Prendergast, John Purroy Mitchel and George McAneny, Committee of the Board of Estimate and Apportionment of the City of New York, dated 2 Wall St., New York City, May 14, 1910. A better understanding of the report will be had if there is first read the following historical account of the project for the tunnel in question, taken from one of the numerous appendixes to the report:

In the report of the New York Board of Water Supply dated Oct. 9, 1905, to the Board of Estimate and Apportionment, a summary is given of the proposed system to obtain a supply of water from the Catskills of 500,000,000 gals. daily. In this report provisions were made for supplying Brooklyn with 100 m. g. d. and Richmond with 20 m. g. d. The distribution of the remaining 380 m. g. d. was left for future consideration.

The plan proposed a steel pipe line from the Hillview Reservoir to the East River, a 10-ft. tunnel under the East River at Port Morris to Long Island and a steel pipe line connecting the tunnel to Forest Park, in Brooklyn.

A cast-iron pipe line was to extend also from the tunnel to the Narrows, passing under them to Richmond. The cost of this work was estimated at $10,224,000.

A reservoir was proposed at Forest Park, Brooklyn, but no provision was made for it in the estimate. No provision was made for a reservoir in Richmond, made necessary for this plan, nor were pipe lines provided for a distribution of the 100 m. g. d. from Forest Park Reservoir to Brooklyn.

To provide for these reservoirs and distributing pipe lines would cost approximately $5,000,000, which added to the original estimate of $10,224,000, makes $15,000,000 the cost of delivering 120 m. g. d.; or about one-quarter of the Catskill supply. The time of completion would be about five years, owing to the length of the Port Morris Tunnel crossing under the East River and the preliminary investigation necessary before the letting of contracts.

To complete this preliminary work, and in place of it to provide in a studied and best manner for the permanent distribution needs of the city, the Board of Water Supply by its letter of Nov. 15, 1909, proposed the work which is the subject of the estimates herewith presented. This letter is based on the Report of the Chief Engineer of the Board of Water Supply of Nov. 1, 1909.

Under date of Dec. 8, 1909, the majority of a committee consisting of the Chief Engineer of the Department of Finance, the Chief Engineer of the Board of Estimate and Apportionment, the Chief Engineer of the Board of Water Supply, and Assemblyman Lindon Bates, Jr., reported to the Board of Estimate and Apportionment; while the report of the minority, consisting of Assemblyman Lindon Bates, Jr., was presented Dec. 10, 1909.

Under date of Feb. 2, 1910, the Chief Engineer of the Department of Water Supply, Gas and Electricity reported on this same project to the Commissioner of the Department of Water Supply, Gas and Electricity.

As stated in the beginning of this report, of which this is Appendix "D," the present commission of two engineers and a geologist was appointed by letters from a committee of the Board of Estimate and Apportionment, appointed March 4, 1910.

about 4,000 ft., throughout its length of nearly 18 miles, at any locally desired pressure (up to its limit of action) by means of pressure regulators; so that no fear of an undue overloading of the strength of the street mains, or of plumbing, need be entertained. Water pressure in cities has money value, and is sought for and quickly utilized whenever available. In the course of years, all fixtures are, when necessary, rebuilt to suit the increased pressure, and meantime any district or single buildings within any district, may be kept supplied at the former pressure, if so desired, by the use of the simple and inexpensive appliance known as a pressure regulator. It is thus made practicably expedient to introduce the more desirable and valuable street-main pressure gradually, and as it may be called for by the water consumers. As reducing insurance rates alone, such increased pressure is palpably of great value.

PUMPING TO BE DISPENSED WITH.—The present high-service pumping above mentioned, amounts to about 75,000,000 gals. daily in Manhattan, 25,000,000 in Brooklyn, and 30,000,000 gals. by the pumps of citizens, 130,000,000 gals. daily in all; costing at the city pumping stations about $400,000 annually; at the private pumping plants a sum difficult to estimate, but by careful inquiry and conservative estimate this has been found to amount to not less than the great sum of $1,400,000 annually; a total of $1,800,000 annually, when the estimates were made, which in a few years will certainly amount to at least $2,000,000 annually, representing a capital of some $50,000,000.

BROOKLYN PUMPING WHOLLY TO BE DISPENSED WITH FOR A TIME.—Nor do even these estimates represent all possible saving in expenses now incurred for pumping. As is well known to the Department of Water Supply, Gas and Electricity, all the pumping stations in the Borough of Brooklyn, both low-service and high-service, the two now costing for operation about $1,000,000 annually, without counting renewal fund and repairs, could be advantageously shut down for ten years, if the Brooklyn distribution system could take its supply of water from the proposed Manhattan pressure tunnel.

Over $200,000 annually is also spent in Brooklyn in the purchase of water from private water companies, which may also be saved.

It is well known that a thorough repair, in most cases a rearrangement, of the Brooklyn pumping station machinery, would quickly pay for itself in a saving of undue cost of operation; but this has not been and is not now possible, on account of the constant great overload and strain to which these works have been and are subjected. To give opportunity, therefore, for a rearrangement or for the rehabilitating of the pumping stations of Brooklyn would be not the least of the valuable services which the proposed Manhattan pressure tunnel would give to the interests of the city.

CONSUMPTION OF CATSKILL WATER IN MANHATTAN.—Returning to the consideration of the idea not to allow any of the Catskill water-supply ever to be distributed in Manhattan Island, we find that within about 30 years no less than 180,000,000 gals. daily of this supply will be needed in the Borough of Manhattan, even if the whole of the Croton water-supply be reserved in addition and for Manhattan, exclusively; which shows that a conduit of some sort from Hillview to Manhattan must be constructed.

CROSS CONNECTION, MANHATTAN-BROOKLYN.—Nor can we assume that there is no value in cross connection of great carrying capacity between Manhattan and Brooklyn. We believe, on the contrary, that a cross connection between these two boroughs, and their main distribution reservoirs, such as the Manhattan pressure tunnel would create, will for all time be of great value in the safe and prudent operation of the water-supply of the great City of New York, and should be acquired as soon as this may expediently be done. To be most effective, it should connect by properly dimensioned conduits the Central Park and Brooklyn Reservoirs.

PARALLEL LINES OF WATER MAINS.—Even then the two plans referred to could not be compared merely on the basis of first cost. A pressure tunnel has practically no maintenance charges, while pipe lines are subject to accidental breakage, if of cast-iron, and to comparatively great renewal charges, if of steel. Especially objectionable are parallel lines of such large pipes laid close together, as they would have to be laid in city streets. Mr. A. Fteley, Chief Engineer of the New Croton Aqueduct, felt so strongly on this subject that he recorded his objections to the eight 48-in. pipe lines laid in Convent Ave. (p. 88 of his Report dated Jan. 1, 1895), even after these pipes had been long laid and in service. Should one such pipe of a parallel row of pipes break, there is always danger of its undermining its neighbors until all the pipes are broken.

There is also to be considered the advantages to the city in having work go on in tunnels, under cover, and without annoyance to street traffic of all kinds; rather than undertake to lay large water pipes in streets already excessively encumbered with underground pipes, conduits, sewers, subways and other subsurface structures with more to come, and with an ever-increasing street traffic, to be served at all times.

FIRST COST COMPARISONS.—But barring those accompanying advantages of the pressure-tunnel plan whose money value cannot be readily computed, our comparisons must be made between the first cost of the proposed Manhattan pressure tunnel, and: the first cost, (a) of a pipe line from Hillview Reservoir through Queens to the Borough of Brooklyn, supplemented by a pipe line from Hillview to Manhattan, together with a cross connection between Brooklyn and Manhattan, all of this of equal carrying capacity and distributing capacity to the Manhattan pressure tunnel first named. Also (b) between the first cost of the proposed Manhattan pressure tunnel and the first cost of a pressure tunnel substituted for the pipe lines just described under letter a; this last being a comparison of first cost between two pressure tunnels built on two different routes.

This Queens and Brooklyn pressure tunnel must, for purposes of enabling a comparison to be made, be supplemented (as was the pipe line) by a good and sufficient pipe line from Hillview to Manhattan, and by a proper direct cross connection, Brooklyn to Manhattan.

Comparing now our estimated probable first cost and time necessary for completion of the Manhattan pressure tunnel, with the estimated probable first cost and time necessary for completion of an equivalent pipe line (your question 2, under letter a) we find that the Manhattan pressure tunnel will cost about $26,000,000, and will require about 4¼ years to construct, while an equivalent pipe line system, will cost about $47,000,000, and will require about 4½ years to construct; a saving of first cost of a pressure tunnel as compared with pipe lines of $21,000,000. For details of which statement, reference is had to Appendices D, E, F and G.

ROUTE COMPARISON.—Taking up our consideration of a comparison of the two pressure tunnels: Hillview via *Manhattan* to Brooklyn and Hillview via *Queens* to Brooklyn (the subject outlined by question 3, b) we are met with the fact that no borings exist on the Ward's Island route. Consequently, over a year's time would be lost on that line in exploring the sub-surface. The topography of this portion of the country shows a large and broad area over which the rock floor is depressed below sea level, and it is known that the zone of disturbed rock occupying in general the valley of East River is broader here than further south. A tunnel on this route would be obliged to cross more rock contacts and traverse greater stretches of poor ground than by the route now proposed.

These conditions argue strongly against the practicability of this route; but on account of a lack of detailed information as to the conditions to be encountered, a comparative estimate of the tunnel: Hillview via Queens to Brooklyn, scheduled under Question 2, b, can hardly be made.

We only know that with equally good ground to be met with, the Manhattan tunnel would cost less; being on a direct and central line that is capable of supplying all the five boroughs; and not needing the supplements of a separate and special line to supply Manhattan, and of a separate and special cross connection between Brooklyn and Manhattan.

QUESTION 3.—Our answer under question 2, b, just stated, naturally applies also to question 3: "Which, in your opinion, is the better route for a pressure tunnel if constructed, (a) from Hillview Reservoir, through Queens, Brooklyn, or (b) from Hillview Reservoir, through Manhattan Island, to Brooklyn?"

CONCLUSION.—If we were tersely to sum up the considerations which are not included in a mere comparison of first costs, as presented by the three questions we have answered and to emphasize the value of the advantages which the proposed Manhattan pressure tunnel will confer upon the city, such as increased pressure gained (a very valuable item in the way of saving fire insurance, and in saving pumping expenses, as already shown) no encumbrance of streets during construction, nor of their subsoil thereafter, and the like considerations, we would say that the City of New York *must have* the Manhattan pressure tunnel to distribute the Catskill water-supply, or its equivalent; and from the results of our studies, we find that the Manhattan pressure tunnel may be constructed at much less cost, with less annoyance and immediate danger during construction, that it will be more valuable in use immediately and in the future, and will cost much less to operate and maintain.

COST ESTIMATE.—The detailed estimates given in full in Appendix "F" are based on contractor's actual costs of similar work in New York City, and prices on similar adjusted to meet the restrictions of the city ordinances. They are conservative and it is believed the contracts can be let well within these figures.

ESTIMATED TIME OF COMPLETION.—In estimating time of completion (see Appendix "G") for rock excavation in shaft and tunnel within city limits, the fact that blasting is not allowed between sunset and sunrise was given full consideration.

Drilling in shafts in residential sections will in all probability not be permitted after 9 or 10 p. m. These conditions, taken in connection with the eight-hour labor law, will cut down progress and enhance costs.

The progress assumed is based on actual performance of similar work in New York City.

OTHER DISTRIBUTION PLANS CONSIDERED.—An estimate was made of the cost of a pressure tunnel to deliver 250,000,000 gals. daily (see Appendix "H") in view of the possible saving in postponing the distribution of the second 250,000,000 gals. daily to some future time. The cost of the smaller tunnel was found, however, to be 76% of the cost of the 500,000,000-gal. daily capacity tunnel.

BUILDING AT INTERVALS.—The cost estimates given in Appendices H and I indicate that a serious loss of money would be the result of attempting to provide for the distribution of the Catskill water-supply by installments of pressure tunnels or pipe lines built at intervals of time, and providing at each time for the distribution of only a part of this supply.

PIPE GALLERIES.—We have considered the suggestion that has been offered, from time to time, these twenty years, that subways for passenger travel, and 66-in. main conduits to convey water placed under about 300 ft. pressure, could economically and with a proper degree of safety be carried in one and the same tunnel excavation. We advise against that mode of either subway or of water-supply construction, for reasons which we assume we need not at this time give in detail.

The Chief Engineer of the Public Service Commission for the First District of the State of New York, writes us:

> The suggestion to use pipe galleries for steel pipe lines 66 ins. in diameter, carrying water under a pressure of 300 ft. head, hardly seems feasible. These pipe lines would take up practically the entire gallery—and I might also add that this department has found the difficulties in the construction of pipe galleries in connection with subway work so great that it considers them impracticable and hopes that they will ultimately be abandoned.
>
> I would suggest that the proposed pipe lines be laid in streets where there are no subways, and that where they cross the proposed subway lines, the locations should be taken up in detail with this department, so that we can advise you as to the proper depth of the pipe lines at the sites proposed. These subway lines have not yet been designed, but I should be pleased to make a special study for you at such points as may be necessary.

WATER-WASTE PREVENTION.—One subject we have not yet touched upon is that of a future restriction of water waste throughout the City of New York and whether it can be made to affect the conclusions we have reached. This is a subject the treatment of which borders on the realms of prophesy. If the government of the great City of New York, through a series of years, were a simple matter, it might be said, with some measure of certainty, what could and would be accomplished during any stated period as regards water-waste prevention. But the course of future events will be governed by a very complex combination of circumstances.

Individually, we thoroughly believe in the work of water-waste prevention now conducted from within the Department of Water Supply, Gas and Electricity, by able men, appointed with a view to having the desired results accomplished. And doubt not that eventually waste will cease to run riot as it has in the long past of New York City; its water consumption attaining possibly the degree of good administration and of thrift which has for 30 years been exhibited by Providence, R. I., a city of some 200,000 inhabitants (about 60 gals. per day per capita); and for shorter periods of time to an equal degree, or for the same length of time to a lesser degree (from 60 to say 100 gals. per day per capita) by many other American cities.

But this will not be accomplished without due and continued effort extending over years of time. Our enquiries on this subject lead us to the belief, in agreement with competent estimates that have been made, that to complete the work of inaugurating a thorough curtailment of water-waste in New York City, may, under favorable circumstances, require eight years.

Meantime, whatever happens, a proper and sufficient supply of water for fire and domestic purposes throughout the City of New York must at all times be furnished; and it is the duty of every one engaged in this incessant work, by the exercise of forethought, to see that nowhere and at no time shall there be an interruption to an adequate supply of water to the city, so vitally important to its welfare. We do not believe that considerations of an attainable reduction of water waste should be allowed to affect any of the work of water-supply now in progress or projected.

We have been greatly pleased, some of us have been agreeably surprised, at the extensive and able study that this project of a Manhattan pressure tunnel has already received. Besides replying to the specific questions put to us, as we have done, we desire again to say, that whether viewed from the point of first cost, maintenance or of future cost, our opinion is that the City of New York will do well to direct the immediate construction of the proposed Manhattan pressure tunnel for purposes of distributing the Catskill water-supply to the five boroughs.

BRIDGES OVER THE ALLEGHENY RIVER at Pittsburg should have a clear height underneath of 40 ft. above pool level, according to the recommendations of a committee of the Chamber of Commerce. This is 3 ft. higher than the clearance recommended by Col. Symons and Mr. Fred. Law Olmsted in their report to the Civic Commission, but is 7 ft. less than the height asked for by the river navigation interests.

Annual Convention of the National Electric Light Association.

The 25th annual convention (and 33d meeting, owing to the practice of holding two meetings a year for the first few years) was held at St. Louis, Mo., May 23 to 27, 1910. The headquarters and place of meeting were at the new Coliseum, which also accommodated the large and varied exhibit of electrical apparatus and appliances. The attendance was large, the total registration of members and guests (including ladies) being given as 2,644. There were 15 sessions held during the four days, four of these being general and the remainder divided between the technical, commercial, company-accounting and power-transmission sections. This last is a new section which held its first meeting. The general entertainments included a reception on the first evening, an evening at one of the pleasure-resort parks, and a visit to one of the breweries. In addition to these, special entertainments were provided for the ladies. With so large an attendance an efficient system of registration is important, and much time and confusion is saved by a system of registering by mail in advance of the meeting. The registration cards form a card index, and as each person applies at the desk his card is removed to an index forming the registration list and he receives his badge, program, etc., in an envelope. Cards of different colors distinguish the list of members of various class, visitors, etc. A separate registration place is provided for those who have not registered by mail.

The opening meeting was called to order about 10.30 a. m., May 24, by the President, Mr. Frank W. Frueauff (Denver, Colo.), and a short speech of welcome was given by Mr. F. H. Kreismann, mayor of St. Louis. The president then delivered the annual address, in which he suggested the division of the membership (which is by companies) into groups based upon the population of the various towns and cities in which the member companies are located. In this way, groups may take up subjects which are of special importance under their own conditions but which are perhaps of less importance to the larger (or smaller) companies. It has been found that comparatively little of the committee work or the preparation of papers for the meetings has been done by representatives of the smaller companies, but it is hoped that under the new arrangement they will take more active participation in the work of the association. Another recommendation in the special interest of the smaller companies was the increased organization of state associations, auxiliary to the main association. A change in the system of dues was proposed, with a view to avoiding the present conditions under which voluntary contributions have to be asked each year to take care of the excess expenses of the convention. At the close of the address, Mr. W. W. Freeman, Vice-President, who was presiding, appointed a committee to consider and report upon the recommendations made in the address. The report of the Secretary and Treasurer, Mr. F. M. Tait, showed a financial balance of $24,370 in cash and investments. The officers elected were as follows: President, W. W. Freeman, Brooklyn, N. Y.; Vice-Presidents, John F. Gilchrist, Chicago, and Frank M. Tait, Dayton, O.; Secretary, T. C. Martin, New York.

The "question box" is a distinctive feature of the association's work, and the editor, Mr. John C. Parker (Rochester Ry. & Light Co.), made a report of the year's work. He suggested that in view of the importance and increasing work of this department there should be a permanent editor working in conjunction with the secretary's office. For the Committee on the Revision of the Question Box, Mr. A. J. Campbell (New London Gas & Electric Co.) presented a report outlining the work in preparing a hand-book for the use of central station operators. A voluminous report of the Committee on Progress, reviewing the progress here and abroad in various lines of electrical work, was presented in brief by the Secretary, Mr. T. C. Martin. A report from Mr. Dudley Farrand (Public Service Corporation, Newark), the association's representative on the National Conservation Commission, was read by Mr. W. Robbins. It briefly reviewed the situation, and stated that in the absence of specific instructions no steps had been taken to support or oppose any of the legislative measures proposed. The report was referred to the Executive Committee. A report of the Accounting Committee was read by Mr. John L. Bailey (Consolidated Gas, Elec. Lt. & Power Co., Baltimore). It reviewed the papers prepared for the accounting section, and particularly a paper outlining a uniform accounting system for small central stations. The report of the Committee on Membership, presented by Mr. H. H. Scott (Doherty Operating Co., New York), reviewed the development in numbers and showed a total membership of 5,522 in May, 1910.

It may be noted that the acoustics of the part of the main hall partitioned off for the general meeting proved extremely unsatisfactory, and the conditions were aggravated by noises from the outside and from the adjacent exhibit hall. After the first session, a rough sounding board was erected on the platform, horizontal wires radiating from this were run across the hall to break up the sound waves, and the large open spaces (with tiers of seats) surrounding the main floor were shut off by drapery. All speakers were then requested to come to the platform and stand under the sounding board when making their remarks, but it was hard to keep them in exact position in spite of frequent cautions from the president. Mr. W. D'A. Ryan received acclamations for delivering his paper at the top of his voice (notwithstanding the discomfort to himself) so that everybody could hear without difficulty.

Power-Station Plant.

The papers relating to power-station plant were not of particular interest or of a high quality, presenting much matter which has been presented already before this and other associations. The main ideas conveyed were the advantages of steam-turbines over reciprocating engines, and of gas engines over any kind of steam units. A paper by Mr. Paul Lincoln (Westinghouse Electric & Mfg. Co.) dealt with "The Space Economy of the Steam Turbine," and showed how in a number of cases the capacity of plants had been increased to a great extent by installing steam-turbine units in the "odd corners" of floor space, without any enlargement of the building. He stated that the 5,000-KW. reciprocating units of the Manhattan Elevated Ry., New York, are the largest ever built, and represent the highest development in size of the slow-speed generator and reciprocating engine, and he thought no further development would be made in this line. At the present time there are a number of 10,000-KW. turbo-generator units in operation, while orders have been placed for machines 50% larger. These are the capacities for the normal (and not the maximum) rating. Where turbine units are installed to increase the capacity of a plant, additional economies can be obtained by the use of an exhaust-steam turbine as one of these units. It is to be noted also that the problem as to the relative arrangement of boilers and prime-movers is very different with turbines than with reciprocating engines. In some cases, a turbine is placed above the boiler room, being carried by the floor framing of the building, which would be impossible with a reciprocating engine.

A paper on "Direct-Current Turbo-Generators," by Mr. W. L. Waters (Westinghouse Electric & Mfg. Co.), stated that while large lighting and power stations are gradually abandoning the use of direct-current generating apparatus, the number of small power stations and isolated plants generating direct current is increasing, and is causing a demand for turbo-generator units. Such units have been built in Europe for 15 years, but they have not been regarded as satisfactory for American conditions. Only within the past five years have satisfactory machines been built in this country, and using carbon brushes in place of the metallic brushes originally used on European machines. While the carbon (or graphite) brushes appear to be essential for satisfactory performance, it has been very difficult to adapt them to collecting large currents at high speeds, but this has been accomplished. The paper dealt mainly with the generator part of the unit.

The report of the Committee on Gas Engines was presented by Mr. I. E. Moultrop (Edison Elec. Illuminating Co., Boston). This was brief and, while the report last year had related to the larger fuel-gas plants, the investigations now presented related to plants using city gas and the smaller fuel-gas plants. It appears that few electric generating plants use any but fuel gas. This was followed by a paper on "The Adaptation of Gas Power for Central Station Service," by Mr. Nisbet Latta (Allis-Chalmers Co.); it was of a very general character, including a discussion of such matters as the smoke nuisance, London fogs, etc. The author estimated that the general adoption of the internal combustion engine would reduce the country's power fuel-bill by about 80%. As to the use of low-pressure turbines he remarked that no engineer would locate such a device in any original installation, its function being to relieve the burden of overloaded stations having large volumes of exhaust steam going to waste. The gas plant has an important advantage in its readiness for immediate use (as when the darkness of a storm suddenly increases the lighting load), while during periods of low load one or more cylinders may be cut out of service.

The members present, however, were not impressed by the varied arguments of this paper, and the discussion was distinctly unfavorable to the gas engine on many points. In the first place it appears to be a common experience that the economy estimated is not obtained in service, and in one case the cost for current thus generated was higher than for current furnished by a central station. In another case, a gas plant required seven times as much water as a steam plant; and the guaranteed cost per HP. could not be realized as no account had been taken of the various auxiliaries. Mr. Condon (Harvard, Ill.) considered the depreciation twice as great as that of a steam plant, due to the corrosive action of the gas; and also that no single gas unit should be installed, on account of the unreliability, which may develop at a full-load period. After complaints as to the low efficiency of his plant it was tested by the builders' experts, who could not make it develop more than 65% of its rated capacity. Another member spoke of the flickering light where the generator shaft is coupled directly to the engine shaft, this being due to fluctuations of pressure in the cylinders during the combustion of the gas.

Distribution System.

An interesting paper by Mr. S. B. Way (Union Elec. Lt. & Power Co., St. Louis) described some "Departures from Standard Practice in Distribution Methods." These included concrete ducts cast in the trench, concrete sheathing for cables, and clamps instead of bolts for attaching pins to cross arms. Some members thought the concrete would be so rough as to damage the cables and would be difficult to break up in getting at a fault, but the author disposed of these objections, and said further that no skilled labor is required in making these conduits. As to the clamp attachments, one member thought these less efficient than bolts, and unnecessary in view of the increasing use of treated cross arms, which do not decay at the pin holes. The report of the Committee on Overhead Line Construction was presented by Mr. F. Osgood (Public Service Corporation, Newark, N. J.), who explained that it dealt only with secondary circuits; it supplements a previous report on primary circuits and is to be followed by one on high-tension work. The three will then be revised so as to form a hand-book. He did not approve of the requirements of the New York Central Ry. as to carrying electric wires over its tracks, but stated that the crossing work described in the present report is the result of conferences with the electrical committee of the

American Railway Engineering and Maintenance of Way Association. Mr. H. B. Gear (Commonwealth Edison Co., Chicago) described the use of side arms instead of cross arms for poles set in the alleys. A paper on "The Location of Faults in Underground Cables" was read by Mr. W. A. Durgin, of the same company; this described methods in use, and also a new method recently devised which reduces the time materially.

The report of the Committee on Grounding Secondaries was read by Mr. W. H. Blood (Stone & Webster Co., Boston), which reiterated the former recommendations for rules requiring the grounding of secondary alternating current systems carrying up to 150 volts. This developed an animated discussion. Mr. A. Maxwell (N. Y. Edison Co.) presented a paper on "The Use of the Oscillograph in Fuse Testing." The report of the Committee on Protection from Lightning described methods suitable for distribution and transmission systems, and also rules for the inspection of lightning-arresting apparatus. The Committee on Preservative Treatment of Poles and Cross Arms presented a lengthy report dealing with various processes and their use, and also discussing the economies of their use.

Lamps and Lighting.

A brief report of the Committee on Lamps dealt mainly with the improved tungsten lamps; this was presented by Mr. W. F. Wells (Brooklyn Edison Elec. Ill. Co.). Mr. C. F. Scott (Westinghouse Elec. & Mfg. Co.) described a new form of tungsten lamp, the special feature of which is the strength of the filament as compared with the great fragility of ordinary tungsten lamps. The filament is made in very long pieces by a special process. Samples of these 118-volt, 15-watt lamps were exhibited and tested. A talk on "Magnetic and Flaming Arcs vs. Open and Enclosed Carbon Arcs for Street Lighting" was given by Mr. W. D'A. Ryan (General Electric Co.), showing a very high efficiency for the Boston, flaming-arc, direct-current lamp of 75 to 80 volts, which is fitted with carbons of special composition and treatment.

A paper on "High Efficiency Lamps" by Mr. S. E. Doane (National Electric Lamp Association, Cleveland), reviewed the ultimate economy to the central station from the use of such lamps. This produced some protracted discussions from central station men. Three commercial papers which may be noted here were as follows: (1) "Decorative Street Lighting," by E. L. Elliott (Illuminating Engineering Co., New York); this was read by Mr. V. R. Lansingh and was illustrated by a number of lantern slides; (2) "Residence Lighting," by H. J. Gille (Minneapolis General Electric Co.); this dealt with the distribution and color of the light, and the effect of the color scheme of decoration upon the nerves and health of the residents or occupants of the house; (3) "Industrial Lighting with Incandescent Lamps," by J. D. Holt, P. F. Bauder and H. S. Hall (National Electric Lamp Association, Cleveland); this dealt with the proper amount and distribution of light in factories, etc., and with the best arrangement of lights at the machines to enable the operators to work efficiently, completely and without injury to their sight.

Power-Transmission Section.

This section was organized as the result of an attempt to organize an independent association of engineers and representatives of power transmission companies. Its first (and only) meeting was held May 26, but resolved itself into a discussion of the acquisition of water power sites and the recent unfortunate upheaval in the government departments connected with this work. The stenographer was directed not to report the proceedings, and some very strong statements were made, but fortunately better counsels prevailed, and it was decided that the speakers who had not been reported should make "moderate" statements in writing for publication in the proceedings. Some of the speakers also, while opposed to the position of the general government, deprecated any general attack such as opened the meeting. Dr. Steinmetz and others remarked that the aim should be to educate the public as to the situation rather than to open a fight upon the government. This discussion was opened by an address by Mr. Henry L. Doherty (New York) on "The Public and the Water Powers."

In the short time remaining, Mr. H. W. Buck (New York) presented a paper on "Present Problems in Power Transmission," and Dr. Charles P. Steinmetz (General Electric Co.) gave excerpts from his paper on "High Potential Line Phenomena." The last paper was by Mr. K. C. Randall (Westinghouse Electric & Mfg. Co.) on "Transformers for High Voltage Work." At another meeting a paper on "Interesting Points of Modern Transformers," was read by Mr. E. G. Reed, of the same company. In the discussion on Mr. Buck's paper, one member instanced a 100,000-volt transmission line in which a pole fell and one wire was severed in two places and the broken ends widely separated (lying on the ground) without causing any interruption of the service. Another line, of 110,000 volts, has been built without fuses, lightning arresters or ground wires, but has been in operation uninterruptedly for some years.

Miscellaneous Papers.

Other papers of a technical character were as follows: (1) "Water Intakes from the Mississippi River for Two Electric Generating Stations at St. Louis," by John Hunter (Union Electric Light & Power Co.); the intake of the Ashley St. section is a well formed by a river wall (with inlets at two levels) and the foundation wall of the station; at the Lewis St. station there are two tunnels (diverging from a shaft) to intake chambers (in solid rock) under the river, from which strainer tubes are driven up to the river and connected with suction pipes in the tunnels. (2) "The Electric Vehicle Opportunity," by Hayden Eames (Studebaker Co., South Bend, Ind.); this related more particularly to delivery wagons. (3) "Electricity on the Farm and the Influence of Irrigation," by Herman Russell (Rochester Railway & Light Co.); this related to the company's development of the use of electricity for pumping, lighting, and power purposes in the country districts including the irrigation of fruit farms in the state of New York; it referred also to the possibilities of electric pumping for irrigation work in the western states. (4) "European and American Switchboard Practice," Stephen O. Hayes (Westinghouse Elec. & Mfg. Co.). (5) "Voltage Control of Generators and Feeder System," F. W. Shakelford (General Electric Co.). (6) "Modern Single-Phase Potential Regulators," E. E. Lehr (Westinghouse Elec. & Mfg. Co.). There were also reports from the committees on Meters and on Protection from Lightning.

Thomas Murray

A number of papers were presented at the sessions of the Commercial and Accounting sections, but few of these would be of direct interest to our readers and we omit mention of these. At the "anniversary" meeting, held on the evening of May 25, Mr. E. A. Sperry (New York), the real founder of the association in 1885, read a paper on "Founding the Association;" Mr. Samuel Insull (Commonwealth Edison Co., Chicago), gave an address on "25 Years of Central Station Commercial Development."

Thomas Murray.

Thomas Murray, who died May 24 at his home in Davenport, Iowa, had been City Engineer of that place for the past 42 years. On the day of his death, Mr. Murray arose apparently in perfect health. Just after he had finished dressing, he sank suddenly to the floor unconscious while talking with his wife. A physician decided that death was due to heart failure, although, as far as could be determined, there was no organic heart trouble.

Mr. Murray was born at Dumfriesshire, Scotland, in 1845. His father, Charles Murray, was at that time salesman for a milling company, but left Scotland for America eleven years later. Thomas was brought to Scott Co., Iowa, by his father with the rest of the family in July, 1856. The remaining years of his boyhood were spent on the 320-acre farm purchased by his father near Davenport. During this period he attended the Davenport public schools. After graduating at the high school, he entered the office of W. Dalton Clark, who was at that time City Engineer of Davenport. When Mr. Clark relinquished that position a year or so later, Mr. Murray was elected by the City Council to succeed him on April 15, 1868. Since that time he has been reelected each year. A letter and an editorial comment on his long term of office was published in Engineering News, Jan. 16, 1908, p. 69.

Mr. Murray had supervised the paving of practically all the paved streets of Davenport, had surveyed practically every lot within its confines and had superintended practically all the grading done since the town became a city. In short, the whole city as it exists to-day has been laid out by Thomas Murray. He was married in 1880 to Eva Daniels, of Davenport, who survives him. His two sons are Sidney Murray, a graduate of Yale University, now studying law in Chicago, and Oliver Murray, a member of this year's graduating class at Yale.

Notes from Engineering Schools.

RENSSELAER POLYTECHNIC INSTITUTE.—The Board of Trustees has recently offered five scholarships to male graduates of secondary schools in New York State. Each scholarship entitles the student to free tuition ($200 per year) for four years. These scholarships will be awarded to the five candidates having the highest marks in examinations given, by the Regents of New York, in subjects required for entrance to this Institute.

Not more than two scholarships will be awarded in any one year to candidates from any one county or state and not more than two in any one year to candidates from New York City. The awards will be made by a committee of the faculty of the Institute. In making the decision the marks in mathematical and scientific subjects will be increased 25% per unit. In order to be eligible for one of these scholarships a student must have been attending one of the schools above described during part or the whole of the scholastic year 1909-10, and he must make written application to the Director of the Institute before July 1, 1910. He must give the name of the school of which he is a graduate or will be a graduate in June, 1910, home address and the name and address of the Principal of the school

Such candidate must obtain from the Board of Regents of New York a certified statement of his marks in the subjects in which he has been examined and must present such statement before Aug. 1, 1910.

JOHNS HOPKINS UNIVERSITY.—Under the joint auspices and control of the University and the Illuminating Engineering Society, a course of 36 lectures will be given in Baltimore from Oct. 26 to Nov. 8. This course was arranged upon the initiative of the Council of the Society and will follow the annual convention of the society to be opened at Johns Hopkins University, Oct. 24.

The University announces three objects of the proposed course:

(1) To indicate the proper coordination of the arts and sciences which constitute illuminating engineering; (2) to furnish a condensed outline of study suitable for elaboration into an undergraduate course; (3) to give practicing engineers an opportunity to obtain a conception of the science of illuminating engineering as a whole.

The University will provide demonstration and experimental facilities for the lecturers and for those who attend. A fee of $25 will be charged. The list of lecturers include the following men: J. D. Ames, Professor of Physics; J. B. Whitehead, Professor of Applied Electricity; J. B Watson, Professor of Experimental Psychology, Johns Hopkins University; E. P. Hyde (President Illuminating Engineering Society), Director of Physical Laboratory; P. W. Cobb, Physiologist of Physical Laboratory, National Electric Lamp Association, Cleveland, Ohio; W. R. Whitney and C. P. Steinmetz, General Electric Co., Schenectady, N. Y.; M. C. Whittaker, Columbia University; W. R. Addicks, Consolidated Gas Co.; J. W. Lieb, Jr., New York Edison Co.; C. H. Sharp, Electrical Testing Laboratories; L. C. Tiffany, Tiffany Studios; L. B. Marks; Norman Macbeth; V. R. Lansingh; L. E. Caldwell; Walter Cook, Vice-President American Institute of Architects, New York City; E. B. Rosa, National Bureau of Standards, Washington, D. C.; E. N. Wrightington, Consolidated Gas Co.; Louis Bell, Boston, Mass.; Walton Clark, United Gas Improvement Co., Philadelphia; A. C. Humphreys, President Stevens Institute of Technology, Hoboken, N. J.

HADLEY HALL, in which were housed the scientific departments of the University of New Mexico, was destroyed by fire on May 23. The loss is stated to be over $100,000. The valuable geological and Indian collections of the University were destroyed.

A DRY DOCK WAS SUNK May 26 at Tietjen & Lang's shipyard, Hoboken, N. J., by the explosion of the boiler of the engine used for raising and lowering the dock. Three men were badly injured.

A FRENCH SUBMARINE WAS WRECKED in the English Channel, two miles from Calais, France, May 26, by collision with the channel passenger steamer "Pas de Calais." The submarine, the "Pluviose," was struck by the steamer at 2.30 p. m. and went down in about 30 fathoms of water, carrying with her the entire crew of 3 officers and 24 men. Efforts made the same evening to raise the hull or release the crew were unsuccessful. The "Pluviose" was 160 ft. long with a displacement of 398 tons.

A FLIGHT FROM ALBANY TO NEW YORK, about 137 miles, was made on May 29 by Glenn H. Curtiss in an aeroplane of his own design. The total elapsed time was 3 hrs. 32 mins.; the time in flight was 2 hrs. 32 mins., an hour's stop being made near Poughkeepsie. This journey, by which the aviator won a prize of $10,000 offered by the New York "World," really ended with the stop on Inwood Hill at 207th St., Manhattan, but after an hour's stop an extra trip was made to Governor's Island, New York Harbor, where the aeroplane was housed. The average speed of flight was 54.07 mi. per hr.

A DECISION IN THE HETCH-HETCHY VALLEY controversy, in connection with the proposed municipal water-supply for San Francisco, has been postponed until May 1, 1911, instead of being decided now by Secretary Ballinger, of the U. S. Department of the Interior. As many of our readers will remember, ex-Secretary Garfield granted the city of San Francisco certain water-supply rights in the Hetch-Hetchy Valley, with the understanding that these would not be used so long as the supply from Lake Eleanor was sufficient. Soon after coming into office, Secretary Ballinger was appealed to by those who think the use of the Hetch-Hetchy Valley for water-storage purposes would destroy its scenic value. Thereupon Secretary Ballinger directed Mr. George Otis Smith, Director U. S. Geological Survey, and Engineers Louis C. Hill and Ernest G. Hopson, of the U. S. Reclamation Service, to report on the subject. These gentlemen finally reported to the effect that Lake Eleanor would be sufficient for the needs of the city for years to come, and that therefore it would not be necessary to utilize the Hetch-Hetchy Valley. Subsequently, Secretary Ballinger notified the municipal authority of San Francisco to show cause why Secretary Garfield's permits for utilization of the Hetch-Hetchy Valley should not be revoked. At a hearing on the subject, granted to representatives of the city of San Francisco on May 25 and 26, the request was made on behalf of San Francisco that the whole subject be postponed until after investigation by a Board of Army Engineers, already appointed by President Taft to investigate and report to Secretary Ballinger on this subject. The Army Engineers appointed for this purpose are Col. Spencer Cosby, Lieut.-Col. John Biddle, and Lieut.-Col. Harry Taylor. Pending a report on the further investigation of the subject, it seems likely that there may be new developments in the water-supply situation at San Francisco. At a city election several months ago, as some will remember, there was a slight majority against buying the works of the Spring Valley Water Co., and a heavy majority in favor of constructing an independent municipal plant. Since that time two companies have been incorporated, it is reported, in the interest of the Spring Valley Water Co. It is stated that to one of these will be transferred those portions of the property of the company which are considered to be absolutely necessary for supplying San Francisco with water, while to the other company will be transferred certain real-estate and other holdings not considered essential for the purpose named. Still later, the new city government of San Francisco asked the Spring Valley Water Co. to submit propositions for the sale of its property divided into two parts along the lines just mentioned. The company has expressed its willingness to comply with this request, and it is possible that before a year has passed there will be another election. If such should be the case, it seems very likely that the people will vote to buy a portion of the property of the Spring Valley Water Co. most essential for a municipal water-supply, and thus that the opposition of the company to both municipal ownership and to utilization of the Hetch-Hetchy Valley by the city will be removed. With this opposition removed, it will remain to be seen how successful the agitation of what the San Francisco people call the "nature lovers" will be to the use of the Hetch-Hetchy Valley for water-supply purposes.

A MAGNIFICENT INTERSTATE PARK is assured by the recent action of the legislatures of New York and New Jersey by which it becomes possible to accept a gift of 10,000 acres of land in Rockland Co., N. Y., and $1,000,000 in money, offered by Mrs. E. H. Harriman, and further gifts, totaling $1,655,000, from J. P. Morgan, John D. Rockefeller ($500,000 each) and others. The full scheme contemplates the purchase of land to connect that given by Mrs. Harriman with the Palisades Park along the west bank of the lower Hudson, together with the extension of the Palisades Park to or near Newburg. The latter park, which is already some 14 miles long, has been acquired during the past ten years by the Palisades Park Commission, a joint body representing New York and New Jersey. Besides the $2,655,000 of private gifts already mentioned, the New York legislature has voted in favor of a State constitutional amendment, permitting an appropriation of $2,500,000 for joint park purposes, and the New Jersey legislature has voted $500,000 for the same purpose. Of the total sum in sight we understand that a portion will be used to make the park extension accessible. The area covered in the westward extension of the Palisades Park includes some of the wildest and most beautiful land in the State of New York, located within a short distance from New York City, Jersey City and the other municipalities in the greater metropolitan district.

THE INITIATIVE, THE REFERENDUM AND THE recall were adopted in Denver on May 17, the first two to apply to all city legislation in the power of the city council and the recall to hold over the heads of all elected city officials. Two sets of charter amendments on each subject were before the voters, of which one set was proposed by municipal reformers and anti-corporation interests, while the other set were counter proposals said to have been designed to deceive the voters. The "fake" amendments, as they were called, were defeated by majorities of 11,000 to 14,000 and the "genuine" amendments were carried by from 3,000 to 4,000 votes. The initiative and referendum may be brought into effect by petitions signed by 5% or else by 15% of the qualified electors; if 5% sign then the questions at issue will be voted on at the next general election; if 15%, then at a special election. To secure a vote on the recall of an official a petition with signatures equal in number to 25% of the total votes cast for all candidates for the office in question at the last election is necessary. The petition must state the reasons for recalling the officer. Unless the officer whose recall is desired resigns then his name, with that of rival candidates, shall be printed on the recall ballots. No officer will be subject to recall within six months after he takes office.

MUNICIPAL OWNERSHIP OF WATER-WORKS AT Denver, Colo., was one of the main issues in a hotly contested local election on May 17. The water company and its friends were badly defeated. Three propositions were voted on: (1) A 20-year extension of the franchise of the Denver Union Water Co., already expired, with private water rates to continue unchanged and with $100,000 worth of "free water" for city purposes. (2) A transfer of all control of water-works matters from existing city officials to a board of five, four to be selected (one each) by four commercial organizations and one to be appointed by the mayor; the board to investigate the water question and to submit to popular vote a recommendation to buy the existing private plant, or to build a new one. Another feature of this proposition was a division of the cost of water service between water consumers and owners of undeveloped or unused property. (3) The creation of a Public Utility Commission consisting of Messrs. A. Lincoln Fellows, Armour C. Anderson, Edwin Van Cise, to serve for 6, 4 and 2 years each, to be succeeded by members elected by popular vote for 6-year periods. The first two propositions were defeated by heavy majorities. The third one, known as the "Citizens' Water Amendment" to the city charter, carried by about 2,000 votes, as compared with some 16,000 votes against the third proposition, known as the "Business Settlement of the Water Question" amendment. The successful amendment gives the Public Utility Commission all the powers of control over all local public-service corporations that were formerly vested in the then existing city authorities. The amendment requires the Commission to make an immediate investigation of the value of the plant of the Denver Union Water Co. and of the cost of an independent system. The Commission is authorized to offer the Denver Union Water Co. $7,000,000 for its property and to give it until July 1 to accept the offer. On Sept. 6, 1910, an election will be held to vote on a bond issue of $8,000,000 to be used either to buy and improve the property of the company, if the latter accepts the purchase offer, or else to build new works. The Commission is authorized to employ engineers, attorneys, etc., and its warrants for running expenses must be paid from the general revenue of the city, regardless of whether a specific appropriation for the purpose has been made by the appropriating branch of the city government. It is interesting to note that on March 20, 1909, a valuation of $14,400,000 was placed on the property of the Denver Union Water Co. by a board of appraisers consisting of Messrs. L. Holman, John R. Freeman, C. L. Harrison and Allen Hazen, with Mr. F. P. Stearns agreeing on all points except the value of the water rights, which he placed at a considerably lower figure. This board represented the city and the company.

COUNTY HEALTH LABORATORIES in New York State have been authorized by recent legislation and a few have already been established. Any board of county supervisors in the State is authorized to establish such a laboratory and provide necessary equipment and staff. It appears that all local boards of health and physicians may avail themselves of the services of such laboratories in counties where they have been established, provided the services requested have a direct relation to public health. It also appears that analyses not related to the public health may be secured on payment of moderate fees.

FIVE BUREAUS UNDER THE STATE BOARD OF Health of Maryland are provided for in a recent act of the Legislature of that State. These bureaus are to deal with communicable diseases, bacteriology, chemistry, sanitary engineering, and vital statistics, respectively. The powers and duties of the five bureaus are set forth in the act as follows:

The Bureau of Communicable Diseases shall secure accurate and complete returns of communicable diseases in Maryland, it shall examine into the prevalence and causes of such diseases and devise means for their control, it shall examine into and investigate epidemics and nuisances and devise means for their control, it shall publish monthly a bulletin for health officers, and perform such other duties and exercise such other functions as the State Board of Health or the Secretary thereof shall designate.

The Bureau of Bacteriology shall conduct inquiries into the nature, source and vehicles of infectious diseases, it shall establish and maintain under the direction of the State Board of Health a properly equipped laboratory. The services of the said Bureau shall be free to all local boards of health and to all practicing physicians of the state for such inquiries concerning infectious and contagious diseases as the said Board may from time to time direct, and to the state vaccine agent for testing vaccine virus; it shall examine into and analyze public and private water-supplies, milk and other foods, and shall perform such other duties and exercise such other functions as the State Board of Health or the Secretary thereof shall designate.

The Bureau of Chemistry shall conduct inquiries into the nature, source and vehicles of infectious diseases, and into the nature and character of sewage, trades'

wastes, and into nuisances and causes of nuisances; it shall examine and analyze free of cost public and private water-supplies, milk and such other foods, drinks, confectionery, drugs, spices and condiments as the Board shall direct; it shall establish and maintain under the direction of the State Board of Health a properly equipped laboratory, and perform such other duties and exercise such other functions as the State Board of Health or the Secretary thereof shall designate.

The Bureau of Sanitary Engineering shall examine into all public and private systems of water-supply and prepare proper maps and drawings of the same for permanent record; it shall examine and patrol as far as possible the water-sheds or catchment basins of all public water systems and investigate and report upon all sources of pollution of public and private water-supplies; it shall investigate and report upon all private and public systems of sewage disposal; it shall inquire into and investigate the water-supply, sewage disposal, ventilation, heating and lighting of schools, asylums, jails, and other public institutions; it shall inquire into and investigate offensive trades and nuisances, disposal of trades' wastes, sewage and other offensive matters and devise means for their control and perform such other duties and exercise such other functions as the State Board of Health or the Secretary thereof shall designate.

The Bureau of Vital Statistics shall supervise the registration of births and deaths in the state of Maryland; it shall receive, file, and compile all such records and shall tabulate and publish the same in such form as shall make them most valuable in the public service; it shall perform such other duties and exercise such other functions as the State Board of Health or the Secretary thereof shall designate.

The State Board of Health is authorized to appoint a chief and assistant chief for each of the bureaus, at salaries not less than $1,500 nor more than $2,400 for the chief and not less than $1,000 nor more than $1,800 for the assistant chiefs. The Board is also authorized to appoint draftsmen, inspectors and other employes. The act as originally drafted called for an annual appropriation of $24,000 for the work of the bureaus. We are informed by Dr. Marshall Langton Price, Secretary of the State Board of Health (Baltimore, Md.), that this appropriation was cut down to $20,000 in the Legislature, and that it was further cut to $10,000 by the Governor when he signed the bill. Up to April 16 it had not been decided which of the bureaus would be established first, but it was thought that the bureau of sanitary engineering would be put on a working basis at an early date.

NEW HAVEN ELECTRIC LOCOMOTIVE.—A 150-ton experimental electric locomotive recently completed by the Westinghouse Electric & Manufacturing Co., and the Baldwin Locomotive Works for the New York, New Haven & Hartford R. R., has been given a series of tests on the electric section of the New Haven line. On one run it hauled 37 loaded cars, a heavy freight engine and a caboose from New Rochelle to Stamford, 18 miles, in 27 minutes, with the track covered with sleet. The maximum speed attained was 49 mi. per hr. During tests in Pittsburg, this locomotive started and accelerated a 2,100-ton train on a grade of 0.3% combined with a 3° curve. An 800-ton train was accelerated at a rate of 0.4 mi. per hr. per sec. This design of electric locomotive was described in Engineering News, Oct. 7, 1909.

Personals.

Mr. Cecil Brown, a director of the Tilbury & South End Ry., of London, England, arrived in New York City May 24, to investigate railway terminal facilities and systems of electrification in this country.

Mr. A. R. Dufresne, Assoc. M. Can. Soc. C. E., formerly District Engineer of Public Works, for the Province of Manitoba, at Winnipeg, has been appointed Assistant Chief Engineer of the Dominion Department of Public Works, with headquarters at Ottawa.

Mr. S. H. Brown, Division Superintendent of the Chicago & Northwestern Ry. at Sioux City, Iowa, retired from railway service June 1. He will engage in private business at Lakeview, Iowa, as Vice-President of a sand and gravel company. Mr. Brown had been in the employ of the Chicago & Northwestern for the past 20 years.

Mr. Joseph H. Young has resigned his position as General Superintendent of the northern division of the Southern Pacific Ry. and has been made President of the Northern Commercial Cos. and the Alaska Steamship Co., with headquarters at Seattle, Wash. In his new position, Mr. Young will have charge of all the Morgan and Guggenheim interests in Alaska and Puget Sound.

Mr. A. D. Bethard, recently Assistant General Manager of the Missouri, Kansas & Texas Ry., at Dallas, Tex., has been made Vice-President and General Manager, with the same headquarters. Mr. C. M. Bryant, formerly Superintendent at Smithville, Tex., has been made Assistant General Manager of the Missouri, Kansas & Texas Ry. of Texas, with headquarters at Dallas.

Mr. Charles Jones, M. Inst. C E., Borough Engineer of Ealing, England, for the past 47 years, has been presented with two portraits, oil paintings, of himself in recognition of his long and faithful service. The larger of the two portraits is to be hung in the town hall and bears the following inscription:

Charles Jones, M. Inst. C. E., Engineer and Surveyor to the Ealing Urban Sanitary Authority from its formation in 1863 to its incorporation in 1901, when he was appointed Borough Engineer, presented to Mr. Charles Jones by the Ealing Town Council, the corporation staff and many other friends.

The latter part of the inscription only was repeated on the smaller portrait which is to be hung in Mr. Jones' residence. In replying to the presentation speech, Mr. Jones said that the secrets of success were courtesy, kindness, suavity and a geniality which would take no rebuff.

In length of service under a single municipality, Mr. Jones even exceeds the late Mr. Thomas Murray, whose death after 42 years as City Engineer of Davenport, Iowa, is noted elsewhere in this issue. In Engineering News of Jan. 16, 1908, mention was made of a Mr. Botham, who served for 50 years as City Surveyor of Salisbury, England, and was then succeeded by his son, Mr. A. C. Botham, M. Inst. C. E.

Obituary.

Charles D. Armour, who was employed as a civil engineer in connection with work on the Ashokan Dam, died May 26 at Davis Four Corners, Ulster Co., N. Y., after an illness of two weeks, aged 24 years. He was a son of Mr. James A. Armour, of Chicago, Ill.

Dr. Robert Koch, the prominent bacteriologist, died May 27 at Baden-Baden, Germany, aged 67 years. He is credited with the first practical adaptation of solid culture media to bacterial examinations; with the isolation of the germs which cause tuberculosis and cholera, and with many other important contributions to the modern campaign against diseases caused by bacteria and other parasites.

John H. Whittemore, formerly President of the Naugatuck Malleable Iron Co., died May 28 at his home near Naugatuck, Conn. He organized the firm of Tuttle & Whittemore, which later became the Naugatuck Malleable Iron Co., in 1858, and was its President for 26 years. He retired in 1900 to devote his attention to other business interests. In 1906 he became a director of the New York, New Haven & Hartford R. R., and retained this position up to the time of his death.

Franklin Clement Robinson, Past-President of the American Public Health Association, died May 25 in the Maine General Hospital at Portland, Me. He was born at East Orrington, Me., in 1852 and was a graduate of Bowdoin College in the class of 1873 and took up post graduate studies in chemistry at Harvard University during parts of two years. He had been Professor of Chemistry at Bowdoin since 1874 and carried out some important research work on disinfectants. At the time of his death he held membership in the American Association for the Advancement of Science, the American Public Health Association, the American Chemical Society and the Society of Chemical Industry.

Charles Cameron Clarke, who was prominent for many years in the service of the New York Central & Hudson River R. R., died May 25 at his home, Briarcliff Manor, N. Y. Mr. Clarke was born in 1823 at Canandaigua, N. Y., and was a graduate of Geneva College. He entered railway service in 1854 as Auditor of the Hudson River R. R. and continued in this position until August, 1856, when he became Treasurer. He served in this capacity for 15 years and was then made Treasurer of the New York Central & Hudson River. After twelve years in this position he was elected First Vice-President of the same road and continued to hold that office until Nov. 9, 1900. At the time of his death, Mr. Clarke was Vice-President of the New York & Harlem River R. R., the New York & Putnam R. R., the Spuyten Duyvil & Port Morris R. R. and the Clearfield Bituminous Coal Co.

George Frederick Barker, Past-President of the American Chemical Society and Professor Emeritus of Physics at the University of Pennsylvania, died May 25 at his home in Philadelphia. He was born at Charlestown, Mass., in 1835 and was a graduate of the Sheffield Scientific School of Yale University in the class of 1858. In 1863 he became Professor of Chemistry at Wheaton College, Wheaton, Ill., and he later occupied similar chairs at the Western University of Pennsylvania and at Yale. He became Professor of Physics at the University of Pennsylvania in 1872 and retired in 1900, due to ill health. He was U. S. Commissioner to the Paris Electrical Exhibition in 1881 and the Philadelphia Electrical Exhibition in 1884, and he served on the jury of awards at the World's Columbian Exposition in 1893. He was a Past President of the American Association for the Advancement of Science and held membership in several other scientific societies.

Engineering Societies.

COMING MEETINGS.

AMERICAN FOUNDRYMEN'S ASSOCIATION.
June 7-9. Annual convention at Detroit, Mich. Secy., Richard Moldenke, Watchung, N. J.

MASTER CAR BUILDERS' ASSOCIATION.
June 15-17. Annual convention at Atlantic City, N. J. Secy., Jos. W. Taylor, 390 Old Colony Bldg., Chicago, Ill.

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION.
June 20-22. Annual convention at Atlantic City, N. J. Secy., Jos. W. Taylor, 390 Old Colony Bldg., Chicago, Ill.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
June 21-24. Annual convention at Chicago, Ill. Secy., Chas. W. Hunt, 220 West 57th St., New York City.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.
June 22-24. Semi-annual meeting at Niagara Falls, N. Y. Secy., J. C. Olsen, Polytechnic Institute, Brooklyn, N. Y.

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.
June 23-25. Annual meeting at Madison, Wis. Secy., Henry H. Norris, Cornell University, Ithaca, N. Y.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.
June 27-30. Annual convention at Jefferson, N. H. Secy., R. W. Pope, 33 West 39th St., New York City.

AMERICAN SOCIETY FOR TESTING MATERIALS.
June 28-July 2. Annual meeting at Atlantic City, N. J. Secy., Edgar Marburg, University of Pennsylvania, Philadelphia, Pa.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.
June 30-July 1. Semi-annual meeting at St. Louis, Mo. Secy., W. M. Mackay, P. O. Box 1818, New York City.

OHIO ELECTRIC LIGHT ASSOCIATION.
July 26-28. Annual convention at Cedar Point, Ohio. Secy., D. L. Gaskill, Greenville, Ohio.

INTERNATIONAL MASTER BOILERMAKERS' ASSOCIATION.—The annual convention at Niagara Falls, Ont., was brought to a close May 27 with the installation of the following officers elected for the coming year: President, A. N. Lucas, Milwaukee, Wis.; Vice-Presidents, Geo. W. Burnett, Albany, N. Y.; J. W. Kelly, Chicago, Ill.; T. W. Lowe, Winnipeg, Man.; John T. Johnson, Los Angeles, Cal., and F. A. Linderman, Albany, N. Y.; Treasurer, Frank Gray, Bloomington, Ill.; Secretary, H. D. Vought, New York City.

Features of the convention were an address by Col. E. D. Meier, of New York City, on the progress and development of boiler construction, and an address by Mr. Daniel B. MacBain, of Cleveland, Ohio, on experiments relating to inequalities of boiler expansion.

Resolutions were adopted opposing the bill now pending in Congress which provides for Federal inspection of locomotive boilers.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.—The preliminary program of papers to be read at the second semi-annual meeting, June 22-24, at Niagara Falls, Canada, is as follows: June 22.—"Changes in Industrial Chemistry Caused by Electricity," Edward R. Taylor; "Notes on the Corrosion of Iron and Steel and Its Prevention," G. W. Thompson; "Vacuum Distilling Apparatus," Philip B. Sadtler; Address of President McKenna, "The Study of Materials as an Element in a Course of Chemical Engineering"; committee report on "Chemical Engineering Education"; "A New Product for Use in the Arts," F. G. Wiechmann.

June 24.—"Chemical Industries of Canada," J. A. DeCow; "The Manufacture and Industrial Applications of Ozone," Oscar Linder; "Problems in Chemical Industry," J. T. Baker; "Arrangement of Filter Presses for Bleaching Oils with Fuller's Earth," David Wesson; "Commercial Manipulation of Refractory Elements for Incandescent Lamp Purposes," Ralph E. Myers; "Underground Waters for Manufacturing Purposes," W. M. Booth; "Loss in Coal Due to Storage," A. Bement; "Nitric and Mixed Acids," Schuyler Frazier; "Plant Design," W. M. Grosvenor.

Thursday, June 23, and Saturday, June 25, will be devoted to excursions to the Lackawanna Steel Co., Wickwire Steel Co., Niagara Falls Power Co., and other industrial plants in the vicinity.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.—The program for the 27th annual convention at Jefferson, N. H., June 27-30, has been announced as follows: June 27.—President's address by Lewis B. Stillwell; "Headlight Test," C. F. Harding and A. N. Topping; "Light Standards," Edward B. Rosa; "Modern Oil Switch," A. R. Cheyney.

June 28.—"Disruptive Strength with Transient Voltages," Charles P. Steinmetz and J. L. R. Hayden; "The Electric Strength of Air," John B. Whitehead; "Vector Power in Alternating-Current Circuits," Arthur E. Kennelly; "Determination of Transformer Regulation Under Load Conditions and Some Resulting Investigations," Adolph Shane; "American Telegraph Engineering Notes in History and Practice," Wm. Maver and Donald McNicol; "Telephone Engineering Around the Golden Gate," Arthur B. Smith; "Interaction of Fly-Wheels and Motors When Driving Roll Trains by Induction Motors," F. G. Gasche; "Recent Progress in Exact Electrical Measurements," Clayton H. Sharp and W. W. Crawford.

June 29.—No sessions; trip to Mt. Washington. In the evening at 6 o'clock there will be a dinner and discussion by the sections committee and section delegates.

June 30.—"Electric Locomotive Design," N. W. Storer and Eaton; "A Method of Determining the Adequacy of an Electric Railway System," R. W. Harris; "Third Rail Construction," Jesse H. Davis; "Power Economy in Electric Railway Operation—Coasting Clock Tests on the Manhattan Elevated Railway," H. S. Putnam.

The social features in addition to the trip to Mt. Washington will include a baseball game and a golf tournament.